MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

ABSTRACT OF THE

Proceedings of the Society of Arts,

WITH LIST OF OFFICERS AND MEMBERS,

FOR THE TWENTY-FOURTH YEAR.

1885-1886.

MEETINGS 336 TO 349 INCLUSIVE.

BOSTON:
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1886.

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1885–86 and 1886–87.

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NOTICE.

The Society of Arts, established in conformity with the plan of the Massachusetts Institute of Technology, as set forth in the act of incorporation, April, 1861, held its first meeting on April 8, 1862.

The objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement in connection with arts, agriculture, manufactures, and commerce. Regular meetings are held semi-monthly from October to May, inclusive, in the Institute building; and at each meeting communications are presented on some subjects germane to the objects of the Society, as stated above.

The present volume contains the abstracts of the communications made during the year ending Oct. 1, 1886, most of the business portions of the records being omitted.

The thanks of the Society are due to the publisher of the *Army and Navy Journal* for the loan of the electrotypes used in illustrating Lieut. Zalinski's paper on "The Pneumatic Dynamite Gun," and to the Creque Manufacturing Company for those illustrating Mr. Creque's paper.

The Proceedings of the six preceding years have been published in the same form as this volume, and the Proceedings of the first seventeen years of the Society are now in active preparation for the press. Copies of the publication may be obtained of the Secretary.

For the opinions advanced by any of the speakers, the Society assumes no responsibility.

LINUS FAUNCE,

Secretary.

Boston, June, 1886.

PROCEEDINGS OF THE SOCIETY OF ARTS

FOR THE TWENTY-FOURTH YEAR.

MEETING 336.

Relative Poisonous Properties of (Illuminating) Coal and Water Gas.

BY PROF. W. T. SEDGWICK.

The 336th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Oct. 8, 1885, President Walker in the chair.

The minutes of the last meeting were read and approved, several new members were elected, and some matters of business were transacted, after which the president introduced Prof. W. T. Sedgwick of the Institute, who read a paper on "Relative Poisonous Properties of (Illuminating) Coal and Water Gas."

Prof. SEDGWICK said: The recent extensive employment for illuminating purposes of the so-called "water" gas, derived from the decomposition of steam by the action of incandescent coal, and enriched with the vapor of naphtha, has excited a vigorous discussion of the question whether this gas is or is not more dangerous to the public health, when distributed for the purposes of illumination, than the ordinary "coal" gas derived from the destructive distillation of bituminous coal. Up to the present time, although opinions, chiefly *a priori*, have been freely expressed in the affirmative, and especially in the negative, in answer to the question, very little experimental evidence has been available.

In view of the possibility of the general substitution of water gas for the coal gas now in common use in Massachusetts, the question has assumed a large public importance, and, accordingly, under the instruction and direction of the State Board of Health, Lunacy, and

that the question which we were endeavoring to answer could have been settled by experiments upon carbonic oxide itself. Investigations of this sort have, indeed, been made by a number of experimenters, and the only point of disagreement between them is as to the effects of very small amounts of carbonic oxide. It is agreed that carbonic oxide is a powerful poison, but it is still a question whether or not the smallest quantities are wholly ineffective.

For our purposes, however, there could be no doubt as to the desirability of experimenting with the two gases as they actually flow from the pipes of the companies which manufacture and distribute them. This was the more necessary because it has been suggested that other gases beside carbonic oxide, occurring in illuminating gas, may be operative in making up its total poisonous quality. We have given the suggestion its full value, and have arranged our experiments accordingly. At the same time, the close resemblance of the symptoms observed in poisoning by illuminating gas to those produced by carbonic-oxide poisoning should have due weight, as should especially the results of Gruber,* who removed the carbonic oxide from illuminating gas, and then mixed the purified gas so obtained with air in various proportions. In atmospheres of this kind, containing sometimes as much as eleven per cent of the gas freed from carbonic oxide, animals (mice) remained for hours, exhibiting merely some stupefaction, and quickly recovered when taken out.

Without denying, therefore, to the other constituents their proper physiological effects when breathed with air, in a mixture of which they form a large proportion, it is probably true that carbonic oxide is the only component of illuminating gas whose poisonous qualities are at present of practical importance to the public health.

According to the report of the State Inspector of Gas and Gas Meters for Massachusetts for 1884, the average amount of carbonic oxide in a number of specimens of coal gas was 5.53 per cent. The amount of carbonic oxide in the water gas at Middletown, Conn., at the time of the experiment, was 30.5 per cent, and at Athol, Mass., 29.2 per cent.

In the selection of rooms in which to perform the experiment, it was our endeavor to imitate, in a general way, sleeping-rooms of medium size as they actually exist. In no case were windows made

* Archiv für Hygiene, I (1883), 168.

window, and two doors. It was plastered, but not free from cracks. Dimensions, $11 \times 12\frac{1}{8} \times 15$.

The dimensions of the other room at Middletown, Conn., were as follows: —

Hight,	7 feet 8 inches,	Capacity, 1386 feet when empty.
Length,	14 feet 4 inches,	
Width,	12 feet 2 inches,	

From this, however, must be deducted several heavy pieces of shelving, cases, etc., estimated roughly at 150–200 feet. It will be seen that the room, therefore, compares very well as to shape and contents with the room at Newton. But it had plastered walls, two doors, and two windows, and not in the best repair, and stood upon an exposed corner. On the whole, however, it was a tolerably close but not a tight room; less tight, if anything, than the room at Newton.

The dimensions of the room at Athol, Mass., were as follows: —

Hight,	8 feet 2 inches,	Clear capacity, 816 cubic feet.
Breadth,	10 feet 2 inches,	
Length,	9 feet 10 inches,	

From this, however, must be deducted about 100 feet occupied by a chimney, a bench, a large case, etc.

Different animals, usually of several species, were placed in different parts of the room — on the floor, on the table, on the shelves, etc. — before the experiment began, and their symptoms carefully noted as the experiment went on. Samples of the atmosphere which they breathed were taken from time to time by entering the room and emptying into a vessel demijohns (generally holding one gallon) previously filled with water. These were carefully stopped with solid corks, then taken from the room and immediately sealed with melted paraffine. The time the samples were taken was carefully noted, and they were afterwards analyzed.

The following is a condensed table showing approximately the results of the experiments upon animals: —

Number of the Experiment.	Kind of Gas Used.	Greatest Inflow per Hour in Cubic Feet of Gas.	Estimated Capacity of the Room in Cubic Feet of Air.	Highest Percentage of Gas observed during the Experiment.	Number of Animals Exposed in the Experiment.	Effects noted from exposure of the animals to the mixed gas and air after—									
						1 Hour.	2 Hours.	3 Hours.	4 Hours.	5 Hours.	6 Hours.	7 Hours.	8 Hours.	9 Hours.	24 Hours.
I.,	Coal,	38	1,140	-	8	None.	Drowsiness.	Discomfort.	Slight effects.	-	-	-	-	-	-
II.,	Coal,	36	1,140	-	8	None.	None.	-	-	-	-	-	-	-	-
III.,	Coal,	50	1,140	3.0	6	None.	Drowsiness.	No further change.	No further change.	No further change.	-	-	-	-	Slight effects.
IV.,	Water,	52	1,900	3.3	5	General insensibility.	Two dead.	Three now dead.	-	-	-	-	-	-	-
V.,	Water,	37	1,150	1.1	4	Severest symptoms. One dead.	- -	-	-	-	-	-	-	-	-
VI.,	Water,	8	1,150	0.7	5	Slight effects.	More marked.	Still more marked.	Vomiting. Convulsions. Insensibility.	-	-	-	-	-	-
VII.,	Water,	15	1,150	0.9	8	Slight effects.	Muscular relaxation. Insensibility.	Insensibility. Convulsions.	Gradual increase in severity.	One dead. All badly off.	Three now dead.	Increased severity of symptoms.	Four now dead. Experiment closed.	-	-
VIII.,	Water,	6	725	1.0	4	Salivation. Urination.	Vomiting, &c. One dead.	Three now dead.	-	-	-	-	-	-	-
IX.,	Water,	6	725	1.0	7	Marked effects.	Insensibility. Vomiting.	Two dead.	Three dead.	Four dead.	Gradual decline.	Still more marked.	All dead.	-	-
X.,	Coal,	6	725	0.9	8	No change.	No change.	Slight effects.	Salivation, and more marked effects.	No further change.	No further change.	Marked symptoms.	No further change.	Symptoms somewhat more marked.	Two dead. The rest stupefied.

I will now give the results to which our experiments have led us, and also certain practical conclusions which naturally follow:—

I. With ordinary gas-fixtures it is generally difficult to get more than three per cent of illuminating gas into an ordinary room. By using one burner alone, it is difficult to exceed one per cent.

II. With coal gas it is a matter of some difficulty to get into an ordinary apartment, through the ordinary burners, gas enough to produce upon healthy animals distinctly poisonous effects. With water gas, on the contrary, it is comparatively easy to get into an ordinary apartment, through the ordinary burners, gas enough to produce poisonous and even fatal effects.

III. It does not follow that because one illuminating gas contains three, four, or five times as much carbonic oxide as another it is therefore only three, four, or five times as dangerous to life.

IV. Our experiments confirm the work of Gruber and others, who claim that carbonic oxide is not a cumulative poison,—that is, the breathing of a small quantity for a long time is not equivalent to the breathing of a large quantity for a short time. A similar conclusion may be drawn for all the constituents of illuminating gas.

We may now illustrate the foregoing conclusions by examples drawn from our own experiments. And, first, as to the difficulty of charging rooms heavily with illuminating gas. (Expt. III., page 18.)

A room containing 1140 cubic feet of space was supplied with four ordinary burners. Through these there entered the room at a tolerably constant rate during twenty-four hours 1200 feet of coal gas. Yet, at the end of the twenty-four hours, the top of the room just above the burners contained a mixture of gas and air of which the former composed only three per cent, while the lower portions of the room showed less than one per cent. Again (Expt. V.), a room holding about the same amount of air, received fifty-five feet of water gas during one and a half hours. At the end of that time the largest amount discoverable in the room was 1.1 per cent of gas in the whole mixture of gas and air.

To illustrate the second conclusion, viz., that it is somewhat difficult to get in enough gas by the ordinary fixtures to kill, if the gas be coal gas, but relatively easy if it be water gas, it is only necessary to note the effects of the two experiments just quoted. In the former (coal gas), after twenty-four hours, the animals, though somewhat

before this Society, and reading a paper on under-ground telegraphy. That paper was chiefly historical, and described the various attempts that had been made to lay wires under ground in Europe from 1840 down to that time.

This evening I propose to call your attention more especially to the progress that has been made in methods of laying electrical wires under ground during the past few years.

Ten years ago the number of wires in use in our American cities was small compared with those in use today. The telephone — the wires connected with which perhaps outnumber those used for all other purposes in cities — was entirely unknown.

Electric lighting had not come into practical use, and the number of telegraph wires was far less than that in use at the present day.

In our American cities, at that time, none of the wires were placed under ground, as electric cables were used only for the crossing of rivers and streams, and such cables were made almost exclusively of gutta-percha-covered wires, because gutta-percha, when kept continually wet, is an excellent insulator, and very durable.

The introduction of the telephone and the electric light, together with the increase of telegraphic communication, has given rise to a great cobweb of wires, extending over the business portions of most of our large cities. So long as there were comparatively few wires overhead, little objection was made to them ; but the immense increase of the last ten years, together with the probable large increase in the future, makes it desirable, on the part of the companies operating these wires, as well as on the part of the public, to have them gathered together in some systematic way, and, if possible, to place them under ground.

The objections to overhead wires are that, where they are numerous, they are continually coming in contact with each other; or, as it is technically called, "crossing up," and it is well known that, when this takes place, one or both of the wires is rendered entirely useless.

In the case of the telephone wires, a large force of men is continually employed in running over the roofs to detect and remove such crosses, and even then the telephone often fails to work just when it is wanted, simply because the wire is crossed with some other

bunched together into a cable of such length as would be used in our largest cities, each wire continues to work practically as well as before, and each wire works entirely independently of the neighboring wires in the same cable. This is true even of the old-fashioned cables in use ten years ago.

When, however, it was first attempted to bunch telephone wires into cables, serious technical difficulties were met with. In the first place, it was found that conversation was very much lowered in intensity when, instead of speaking over an overhead wire — say five miles in length — it was attempted to talk over a cable-conductor insulated with gutta-percha of the same length. But, worse than this, it was found that conversation carried on over one wire was heard with equal facility on all of the other wires in the same cable.

This decrease of intensity is due to what is known as retardation, by means of which each signal, instead of being sharp and distinct, is partly kept back, so that it overlaps, and mingles with the next. In the case of a telegraph instrument, the signals do not succeed each other with sufficient rapidity for the retardation to be noticeable on lines of such length as would be used in any of our cities.

In the case of the telephone, the electrical undulations in the wire, by means of which speech is transmitted, necessarily succeed each other some three hundred times per second, and in a gutta-percha cable, five miles in length, a considerable retardation and consequent overlapping of the signals, resulting in a diminution of the intensity of conversation, are felt.

The overhearing, or cross-talk, may be due either to a direct leakage between the conductors, or to what is technically known as induction, by means of which signals sent on one wire cause fac-simile signals in all the other wires, even though there is no direct passage of electricity from one wire to the others. Here, too, in the case of telegraph apparatus, the induction is not sufficient to affect even the most delicate apparatus in use. In the case of the telephone, however, the induction is amply sufficient for overhearing in a gutta-percha cable five miles in length.

The retardation in any cable is directly dependent on the specific inductive capacity of the material used to insulate each wire from its neighbors; and it is evident that a cable which will present the least

retardation is the one whose insulating material has the lowest specific inductive capacity.

The cross-talk — so far as it is due to leakage — is, of course, prevented by using an insulating material of very high insulating power. So far as it is due to induction, we also want to choose an insulating material of low specific inductive capacity, for the cross-talk is directly dependent upon this quality.

The requisites of a cable, then, in order that it may transmit speech without cross-talk, are good conductivity, high insulation, low specific inductive capacity.

Below is a table showing the specific inductive capacity and insulation of various insulators. The measurements were all made on a wire 0.05 of an inch in diameter, coated with insulation to a thickness of 0.10 of an inch: —

CABLE.	MAKER.	Insulation per mile in megohms.	Specific inductive capacity.
Gutta-Percha, .	Siemens Brothers, London, ...	190	4.2
India-Rubber, .	Rattier, Paris, ...	170	3.7
Kerite, ...	A. G. Day & Co., New York, ...	150	4.0
Faraday, . . .	Faraday Cable Works, Cambridge, Mass.,	15,000	1.6
Patterson, . . .	Western Electric Co., Chicago, ...	450	3.1
Brooks, ...	David Brooks, Philadelphia, ...	-	2.8

Let us take a special case, and compare a gutta-percha cable, having a specific inductive capacity of 4.2 with a Faraday cable of 1.6.

The table predicts that we can talk three times as far with the latter as with the former, and experiment proves it. The cross-talk on the gutta-percha cables ought to greatly exceed that on a Faraday cable; and experiment has shown that, while conversation over a two-mile gutta-percha cable was continually disturbed by existing cross-talk, conversation was carried on over a similarly-constructed Faraday cable, five miles in length, without cross-talk being appreciable.

We have seen, from our table, that india-rubber and kerite, both of which are extensively used for telegraph cables, are equally unfit

with gutta-percha for telephonic work, on account of their specific inductive capacity being nearly as high as that of gutta-percha.

There are two other cables mentioned in the table. The Patterson cable, which has a specific inductive capacity of 3.1 against 4.2 for gutta-percha, and the insulation of which, when new, is 450 megohms per mile, against 190 on the part of gutta-percha. The table predicts that a Patterson cable — which consists of cotton-covered wires soaked in paraffine, and drawn into a lead pipe — ought really to be more suitable for telephonic work than is a gutta-percha cable, and experience bears out this prediction.

There is one fatal objection to the Patterson cable, which has been proved by experience with it in France, Germany, and other places: the insulation, although high at first, gradually decreases, and experience has uniformly shown that, after several years of use, this insulation falls so low that cross-talk easily appears, due to direct leakage.

Patterson cables, of course, under different names, were used years ago in France and Germany, and were looked upon with a great deal of favor when first introduced, but the gradual failure of insulation has caused them to be almost entirely abandoned abroad.

Another cable referred to is the Brooks, which consists of copper-covered wires wound with cotton, and drawn into iron pipes, which are then filled with petroleum.

The specific inductive capacity of a Brooks cable is only 2.8 against 4.2 on the part of gutta-percha, and on this account it is suited to telephonic purposes. The Brooks cable, however, like the Patterson, does not retain its insulation, and, indeed, the difficulty of maintaining good insulation in the Brooks cable is far greater than in the Patterson, for it is almost impossible to make the pipes so tight that the petroleum does not leak out, or water leak in.

In the table, I have assigned no value to the insulating power of the Brooks cable, for when the pipes are thoroughly dried, and the cables, after being thoroughly dried, are drawn in, and the pipes are filled with dry oil, the insulation is enormous, and such a cable gives wonderfully good results when used for telephonic purposes, talking excellently well, and being remarkably free from retardation and cross-talk due either to induction or leakage.

The insulation, however, falls continually, and at the end of

returning over the other. Many such pairs of conductors may be bunched together into cables for as great distances as five miles without cross-talk. For in each pair of conductors there are equal and opposite currents which, either by leakage or induction, would tend to produce equal and opposite currents in either branch of any neighboring conductor, or, in other words, no current at all.

This device, therefore, prevents cross-talk, whether due to leakage or induction, and, with cables constructed in this way, the retardation is at a minimum, although experience shows that it is much easier to talk over five miles of single-conductor cable made on the Faraday plan than it is to talk over five miles of metallic gutta-percha cable, such as is used in Paris.

The retardation in Paris is, however, not large enough to be an obstacle for as great distances as it is ever necessary to use within the city. If it were desired to talk through such conductors, and then out across the country to neighboring cities, as we have occasion in America, it is an open question whether the retardation would not become a serious obstacle.

A great objection to the metallic circuit cable is that it requires two wires for each subscriber, which, to say the least, doubles the cost. Moreover, there has never yet been devised any real practicable method of connecting a metallic circuit system with a single circuit system so that conversation could not be carried on between parties in one city and parties in a neighboring city, unless both cities, as well as intervening trunk lines, were constructed with metallic circuits.

Thus far we have merely discussed the electrical difficulties which are met with when we take our wires down from the house-tops and poles, and bunch them into cables, to be laid under ground.

A bird's-eye view of the wires in any of our cities would show that there is an enormous engineering difficulty in the way of placing absolutely every wire under ground. The best solution of this difficulty has been found to be to radiate, by means of cables containing a hundred or several hundred wires, from the central office to a considerable number of points so located about the city that one or another of them could be conveniently reached by a short overhead line from any subscriber's station. This has been done to a considerable extent in many American cities by means of cables carried over-

The method of computation used was the one which would most naturally suggest itself, there being a variety of methods possible. He found the diameter of the wire itself would have to be three inches, and the diameter of the completed cable thirty-nine inches.

MEETING 338.

Improvements in Steam-Heating.

BY MR. FREDERIC TUDOR.

Application of Solar Heat to the Warming of Buildings.

BY MR. S. H. WOODBRIDGE.

The 338th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Nov. 12th, at 8 P. M., Prof. C. R. Cross in the chair.

After the reading of the minutes of the previous meeting, and the election of new members, the chairman introduced Mr. F. Tudor, of Boston, who read a paper on "Improvements in Steam-Heating."

Mr. TUDOR said: The two objections to steam-heating are water-hammering and absence of control of temperature. The first is the result of bad design or workmanship, or of mismanagement of the valves. I shall try to show how both can be obviated. The circulation depends upon gravity, and upon very slight differences of pressure in the several parts of the apparatus, this difference of pressure having no necessary relation to the boiler pressure. Whether the boiler pressure be ten pounds or one hundred pounds, the circulation is not affected, except that difficulties may arise from a difference in the rate of condensation, which is greatly increased by greater pressures, since high-pressure steam has a higher temperature than low-pressure steam. The flow of steam through the great length of pipes, necessary in most cases, is attended by friction and a consequent reduction of pressure at remote points. In a well-proportioned appa-

tem until we reach the vertical, we shall have the common type of radiators disposed vertically, with upright rising mains, and the reason circulation is good, notwithstanding a largely reduced pressure is sufficiently clear.

If, in the horizontal system, the main-return is placed below the water-line, the loss of pressure in the radiators will be balanced in the return-pipe by an elevation of the water-columns in the upright branches, and the circulation will be perfect, notwithstanding the differences of pressure.

The details of the apparatus I have described are commonly supposed to be especially suitable to a low pressure,— that is, of two or three pounds per square inch; but, since the circulation does not depend upon pressure, the system is suitable for any pressure. In passing, I will say that a high-pressure apparatus, so called, is one so badly proportioned that there can be no return to the boiler of the water of condensation which accumulates at the remotest point, where there is the greatest loss of pressure, whence it must be removed by special apparatus.

It has appeared that, in an apparatus of good design, slight differences of pressure are unavoidable, but that there must be a limit beyond which they must not go. Suppose, now, we limit the boiler-pressure, so that it shall not exceed that of a water-column whose hight is equal to the difference of level between the water-line of the boiler and the bottom of the radiator. We can then impose an artificial obstruction in the steam-pipe and graduate its flow, even shutting it off altogether, without deranging the circulation in other radiators. This obstruction is the steam-valve, which, under these conditions, we can open more or less, and obtain more or less heat. We cannot usually do this, because the pressure is too high in the case of horizontal systems having the returns sealed by water-columns; and in the vertical systems, the returns not being sealed, there would be a reversed current in the returns if the supply were throttled, steam would flow in from the return-end and the condensation-water would be driven back and retained in the radiator. Consequently, there is no control of the supply of steam and of the heat emitted; the valves must be wide open or tightly closed.

The method of regulating the heat by limiting the pressure, and thus affording a control over the steam-current in horizontal water-

This valve will be acceptable to all those people who have learned that steam-radiators must be either fully turned on or wholly shut off, and have asked why we cannot turn on steam just as we do gas or water, and graduate the discharge in a similar simple way.

In conclusion, I think I may say that the ground we have gone over brings us to a point whence we can see the two main objections to steam-heating overcome; we can prevent noise in the pipes and graduate the temperature, and, while we have not complicated the construction, we have greatly simplified the management.

In the discussion which followed the paper, in reply to a question as to the relative values of the different methods of heating,—that is, by the old-fashioned fire-place, the furnace, and steam,—Mr. Tudor said that undoubtedly the fire-place was the most cheerful, but, on account of the enormous draft occasioned by large fires, the influx of cold air near the floor caused great variations in temperature at different parts of the room. If this entering air was moderately heated (not too warm as to spoil the draft), this method would perhaps be the best. Heating by a furnace, as compared with steam, is simpler and more manageable, especially in regard to the control of temperature, but it is only suitable to very compact houses, unless several furnaces are employed. Heating by steam gives the very great advantage of transferring the heat to comparatively distant points, and the objection to it is mainly in the lack of control of temperature in the apparatus as generally supplied. The quality of furnace-heating has been much lowered by competition of manufacturers, who now seem to aim to catch purchasers by some taking mechanical detail rather than by general excellence. The most thorough work in furnace-heating is cheaper than the poorest, as well as better, in some cases, than the best work in steam, yet the furnace men have been so occupied by their struggle to sell the cheapest heater in the market that they have lost sight of the fact that they could compete in merits with steam as well as in price.

APPLICATION OF SOLAR HEAT TO THE WARMING OF BUILDINGS.

The chairman then introduced Mr. S. H. Woodbridge, who read a paper on the "Application of Solar Heat to the Warming of Buildings."

because of the loss of heat due to the increased depth of atmospheric medium through which the sun's rays pass as its distance from the zenith increases. In considering the solar heat absorbed by a vertical solar wall, Mr. Woodbridge estimated the losses due to all causes as follows: —

By cloudiness, ...	0.55,	remainder,	0.45
" frame obstruction, ...	0.05,	"	0.427
" angle of incidence and atmospheric absorption,	0.40,	"	0.256
" reflection from glass surface, ...	0.10,	"	0.231
" reflection from slate surface, ...	0.05,	"	0.22
" cooling through glass, ...	0.20,	"	0.176

$42.7 \times 0.176 = 7.52$ B. T. U. per square yard per minute would, then, be the mean heat available through the day hours of the winter season. This estimate he considered high rather than low. It makes the thermal value of a square yard of Southern and vertical sun-exposure, for the six winter months, equal to eighty-one pounds of coal, and twenty-five square yards would yield the heat given by a ton of coal. But coal costs less than $5 per ton to large consumers, and if the cost of twenty-five square yards of solar heating-surface be $225 (the rate of cost of the Athenæum surface), and interest be counted at five per cent, and repairs at three per cent, the cost of solar heating would be nearly $18 for the same quantity of heat yielded by a ton of coal, or $10, if the first cost of the surface were reduced to $125 (the lowest rate of cost of construction given by builders). This estimate makes no account of the heat which the uncovered wall would absorb, and in part transmit, by conduction, through the wall to the maintenance of inside warmth.

The second part of Mr. Woodbridge's paper referred to the effect enveloping a building in glass may have in retaining its heat, his estimate having been made with reference to the new building. The ratio of heat-loss through equal areas of 18″ brick wall and single glass is 1 to 4. The ratio of area of total wall to total window is 22 to 12. The ratio of loss through wall-area to that through window-area is, therefore, 22 to 48. The saving effected by glass over glass is one-half that otherwise lost through single glass, and the saving by glass over brick is one-fifth. The ratio of actual saving per equal areas is, therefore, brick 0.2, and window 2, and the saving for the

Lieut. SPRAGUE said: The necessity for additional means for rapid transportation in New York is most urgent. In considering how the capacity of the roads may be increased, it is necessary to note the character of the roads and their method of operation, and, for that purpose, we will take the Third Avenue line as an example. This is about eight and a half miles in length, the grades varying from eight to one hundred and five feet to the mile, with about one-third of the distance level. In the seventeen miles of single track there are fifty-two stations. Hence, three times in every mile, on an average, a train has to start a weight oftentimes as great as ninety tons from a dead rest, raise it up to a speed of nearly twenty miles an hour, propel a short distance at that speed, overcome not only the inertia of the train and the traction which is required for the train on a level, but also climb grades, and then suddenly bring the train to a rest. All this must be done in one and one quarter minutes.

The mean traction of the locomotives is four times that necessary to draw the train at its mean speed of fifteen miles an hour on a level, and in getting under way, and climbing the one hundred and five foot grades, the traction is at least ten times this amount. The acceleration of the train on the down grades, and the momentum stored up in the train in getting under way, play but little part, except on the down grades, in propelling the train, because the stoppages are so frequent, and at such short intervals, that advantage cannot be taken of any of this stored-up energy. Hence, a large proportion of this is thrown away. With cars of a seating capacity of forty-eight, and room to accommodate forty more standing, it is evident that the capacity of each car of the train cannot well be increased, and the capacity of the trains can only be increased by increasing the number of cars. There are already sixty-three trains in operation at one time on this road during commission hours; they run at very close intervals, and they must be under the most perfect control. Every car added increases the momentum of the train, rendering it more difficult to quickly and efficiently check the speed, and increasing the liability of, and danger from, any derangement of the brake apparatus, especially where dependent upon one source. If the length of the trains be increased,—admitting that they can be handled without difficulty,—the engines will be forced to a duty much beyond that for which they were constructed.

Furthermore, when the tracks are in a slippery condition, the weight of the engines does not give sufficient tractive power to promptly get away from the stations. An additional car will render this delay more frequent, and tend to reduce the traffic-miles per hour run during commission hours.

To get increased traction in the present system it is absolutely necessary to increase the weight of the locomotives, but such increase of weight is useless unless it be effective on the drivers; but if effective on the drivers, then we have an increased dead weight applied to the superstructure of the road at one point Therefore, since the shearing safety-limit of the superstructure has been nearly reached, it would be very unwise to increase the capacity of the road by increasing the weight of the locomotives.

Two ways, however, remain by which the capacity of the roads can be increased: one, by increasing the number of cars in a train, provided it can be done without increasing the weight of the tractive power, or if it can be distributed and the train remain under absolute control; another, by increasing the mean running speed.

Increasing the length of the train will not produce any very much greater strain on the structure, because the columns are only forty-three feet apart, and the cars about forty-six feet long, so that the weight of a dozen cars would not increase the shearing or tensile strain beyond that due to two cars.

To get a higher speed of the trains it is probably necessary to increase the power, and, at the same time, to increase the traction. This increased traction, however, must be distributed; it cannot be put at any one point. It is not practicable to increase the number of trains materially, because they run as closely as can be with safety.

We see, then, that steam-locomotion does not present many opportunities to better the conditions of the road. Hence, we are obliged to turn to some other method, and that which promises the most satisfactory solution is an electrical system.

I have for a long time been elaborating such a one, and am now convinced that this is the future method of propulsion for the trains of the elevated roads, and it is a near future.

In the substitution of one system for the other, what is the object sought? Ultimately, of course, it is a greater return for a given investment, and it is to be obtained in one or more of three ways:

First. By decreasing the coal expended per passenger carried, if this is practicable.

Second. By reducing the wear and tear of the motive power, but more particularly that of the road-bed.

Third. By increasing the carrying capacity of the roads.

The saving of labor I do not think one of the objects to be particularly striven for, the handling of passengers and trains probably never requiring a less number than are now necessary.

It is evident that if any decrease in the wear and tear of the superstructure can be accomplished a great saving will result. By a system of electrical propulsion the power can be distributed underneath the cars,—every car, or two cars if need be, being a unit,—and at the same time arrangements can be made for propelling five or six cars under simultaneous control. By distributing the power under the car, the whole weight of the car and passengers can be made effective for traction, such traction-weight being six times as great as is afforded by the present locomotives. This will enable the cars to be started more promptly, brought to speed more quickly, and stopped in shorter intervals, increasing the mean rate of speed, and thereby the capacity of the road.

Weight is the necessary practical adjunct for traction. The elevated roads present a peculiar problem. To attempt to solve it by replacing the present locomotives by electric locomotives of lighter weight, or even of the same weight, is to shut our eyes to plain mechanical and engineering truths, and does not advance by one single step such solution. The making of cars individual units of locomotion will enable the intervals between trains to be made one-third those of the present schedule for a large part of the time. This would greatly increase the number of passengers during the day and night who would make use of the elevated roads, and this, too, without materially increasing the running expenses.

Another important advantage will be the great reduction in the vibration and wear and tear of the superstructure by distributing the weight so much more evenly. The weight upon the lattice-girders between columns would always be less than two-thirds, sometimes only one-third that now existing, the vibration, tensile, and shearing strains being nearly in the same proportion. The motive power being rotary, the train would start more smoothly, and the motive power be

proportion of this being given back in stopping and running on down grades, it is evident that the energy required in the system is that necessary to move the trains continuously on level grades with a percentage for loss of reconversion added. This is one of the very great advantages of an electric railroad, where grades and stoppages are frequent, and a large number of trains operated. By this method referred to, it is an easy matter to reduce the speed of a train to a third or fourth of its maximum, the breaking-power being under perfect control. If, say, to one-third speed, then since the energy of a moving body is proportional to the square of its velocity, eight-ninths of the train-energy is available for the first step of breaking; that is, $\frac{8}{9} \times 2,105,400$ ft. $= 1,871,400$ ft. lbs. At least seventy-five per cent of this will appear as current delivered back to the line, or in one round trip there will be saved 72,976,800 ft. lbs., of which eighty per cent will appear as effective tractive work again on the axles; that is, it relieves the main generating station of the supply of 58,381,400 ft. lbs. of energy. Also, seventy-five per cent of all the energy of falling, in excess of traction, will appear in the form of current, of which eighty per cent will become effective for tractive power. This amounts to 17,028,000 ft. lbs., which, added to 58,381,-400, gives 75,409,400 ft. lbs. of effective work recovered. This, subtracted from the total work per round trip — 194,799,000 — leaves 19,390,600 ft. lbs. net power expended per round trip, an average of 43 H. P. per minute, or a total of 2710 H. P. for sixty-three trains.

This is the net effective power at the trains which is required to operate sixty-three trains of eighty tons each, as against 4650 H. P. in the present steam-plant, a difference of 1925 H. P., or forty-one per cent in favor of this system.

But the electrical power must be generated at one or more central stations, transmitted to the motors, and then reconverted into mechanical work,— the original mechanical work of the engine suffering from two conversions and one transmission. Experience shows that, with a good distribution and properly-constructed motors, sixty per cent of the original will appear as effective work on the car axle. Then for any electrical system not using the Sprague system of breaking, but with other losses the same, there will be required at the central station $\frac{100}{60} \times 4429 = 7382$ H. P.

With the Sprague system nearly every motor coming to a station

or running on a down grade becomes a generator which is helping to supply the current needed to operate the remaining trains.

This method has already been shown to save about forty per cent as against any other electrical system.

Again, instead of the current being all supplied by the main generating station at one or two points, it is supplied from nearly as many moving stations as there are trains slowing down or running on down grades. With any given size of conductors and average potentials this would greatly reduce the loss, or, with the same percentage of loss on line, the main conductor would be very much smaller, because less current is supplied from the central station, and it is transmitted a shorter distance. The relative size of conductors necessary would be about as one hundred to forty-five, a saving of fifty-five per cent in favor of this system. In the Sprague system there would be required at the central station $\frac{100}{60} \times 2710 = 4520$ H. P., something less than that developed on the present locomotives, which is 4650 H. P. That is, the losses of two conversions and one transmission is more than counterbalanced by the amount saved in this system of breaking.

The present engines have to use a good grade of coal, which costs, ready for use, $4.00 per ton. The duty of these engines is about six pounds of coal per horse-power per hour. Large stationary engines can be relied upon to develop horse-power per hour on three pounds of a lower grade of coal, such as a mixture of anthracite dust and bituminous coal, which can be delivered to the furnaces for $2.50 per ton. The ratio of expenditure for coal would be found as follows: $\frac{4730}{4520} \times \frac{6.00}{3.00} \times \frac{4.00}{2.50} = 3.30$; that is, for every $3.30 spent for coal in the present steam-plant, there would be expended $1.00 in the Sprague system, a saving of about seventy per cent. Against this, and some present labor expenses, must be put the cost of running the central stations.

Another consideration — which must be taken into account when a part of the energy of the trains is returned to the lines, as I have described — is the great saving in the original investment at the central stations as well as in the conductors. In the particular instance here given there is a difference in the power to be provided for at the central stations of 7382 — 4520 = 2862 H. P. The saving on this would, for lots, buildings, boilers, engines, dynamos, and fittings, be

not less than about $150 per H. P., or $429,C00. There is nearly a proportional saving in the labor, depreciation, and the incidental expenses of the central station. Again, since the motor system affords a very perfect system of breaking, neither vacuum nor pressure brakes need be used, although the hand brakes would, of course, be retained.

As a somewhat remarkable corroboration of theoretical by practical work, I would refer to the account of Mr. Angus Sinclair's work in the *Scientific American* (Supplement of October 3d). Through the courtesy of Col. Hain, Manager of the Manhattan Road, Mr. Sinclair, assisted by Mr. J. D. Campbell, general foreman of the Elevated Railroad machine-shops, made a very thorough test of the capacity and performance of one of the standard engines on regular duty. The engine was indicated for two round trips; that is, over a run of about thirty-four miles, and all other necessary data taken. The average power used during the whole distance was 77.8, ten per cent of which is allowed for friction of the engine, leaving net 70 H. P. This by actual experiment.

By theoretical determination I get 70.3 H. P., which includes five per cent friction, or a net of 67 H. P. The difference is 3 H. P., or $4\frac{1}{8}$ per cent, which may represent the excess of weight of the trains tested.

I have presented these facts about the present and future of the elevated roads of New York for your consideration, not because you are particularly interested in New York, but because the problem of rapid transit in Boston has become one of the urgent needs of the present. As the elevated roads there met with great opposition, so has the project of reaching the suburbs of Boston roused a host of objectors. The reasons for this are in part sound. Your streets are, many of them, narrow and crooked. Property owners along the route object to a double-track system of roads extending the full width of a street, to the noise, the steam, the water, the oil, the vibrations, the dirt and cinders incident to a steam system.

But the elevated roads of New York were projected some years ago. Active minds of engineers and inventors have worked out improved methods of construction for the special needs of cities like Boston, where trains may be required to go by one street and return by another. Such roads can be built, the structure of which will not take up as much room in the streets, and will not obstruct the air and

light over one-half as much, as the New York roads, and I feel confident they can be built for less money. With electric propulsion you can have rapid and smooth-running trains of one, two, or more car units. The strain on the structure being much less than in a steam-plant, the whole structure can be made lighter in the same proportion. Dust, smoke, cinders, oil, and water will disappear. Power will cost less. Trains can be run at shorter intervals, and under more perfect control. The energy of the train will become available for the purpose of braking. Repairs of superstructure will be less. In short, electric propulsion, more than any other thing, will make practicable for Boston what it has so long and so sadly needed, — rapid transit to its suburbs. I need hardly point out to you the increase in the value of this property which will more than pay the cost of the roads.

After some discussion the meeting closed with a vote of thanks to Lieut. Sprague for his very interesting paper.

MEETING 340.

The Pneumatic Dynamite Gun, and the Use of High Explosives in Warfare.

BY LIEUT. E. L. ZALINSKI, U. S. A.

The 340th meeting of the SOCIETY OF ARTS was held at the Institute on Wednesday, Dec. 23rd, at 8 P. M., President Walker in the chair.

After the reading of the minutes of the previous meeting, and the election of new members, the President introduced Lieut. E. L. Zalinski, U. S. A., who read a paper on "The Pneumatic Dynamite Gun, and the Use of High Explosives in Warfare," illustrated with numerous views shown on the screen.

Lieut. ZALINSKI said: The first pneumatic gun presented for experiment by Mr. Mefford, the first designer, consisted substantially of a brass tube two inches in diameter, one-quarter inch thick, and

copper capsules of fulminate were used with similar results. A noticeable fact was that shell, charged with seventeen pounds of dynamite, having the percussion-capsule in front, upon striking and exploding sometimes produced comparatively slight effects. I account for this on the assumption that time is required for the explosion of the entire charge; that the gases evolved by the explosion of the layers in immediate contact with the target tended to throw back the gases afterward evolved from the portions of the charge in the rear. It therefore appeared desirable to make the initial point of explosion at the rear point of the charge, and, to prevent an explosion at the point from simple impact, the explosion must take place an instant before the body of the projectile had actually struck the target. To do this I devised an electrical fuse, which could be placed at any point within the charge, and, while not abnormally sensitive to shock while in the bore of the gun, would act upon the slightest touch when striking the target. This consisted of a chloride of silvery battery with suitable circuit arrangements and electrical primers. A very small battery suffices to give a current which would bring the platinum wire-bridge of the fuse to a red heat, and insure the ignition of the charge.

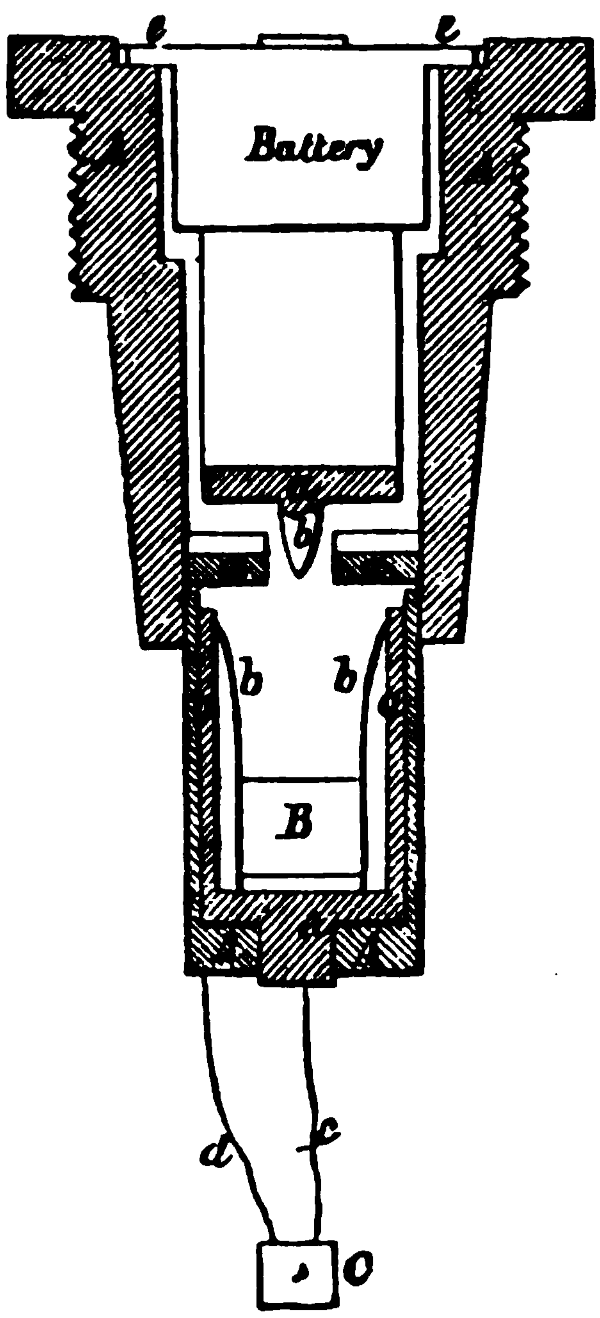

FIG. 3.

The diagram, Fig. 3, is a section of the fuse and connections, in which A is the fuse case, B a metallic plunger, inside the vulcanite cylinder *a*; the contact springs *b b* are attached to the wire *c*, joining the electrical primer C. The second wire *d* goes from the primer to the metallic fuse case. The primer is thus in contact with one pole of the battery placed within the upper part of the fuse case. As will be seen, this battery is suspended to the fuse case A A by thin projections *e e*, which are

get, the pole *a* of the battery comes in contact with *b*, and the circuit is closed through the primer, which explodes the charge from the rear. The actual time required to produce explosion before the full impact of the shell took place was $\frac{1}{1000}$th of a second. Plungers arranged to close up to a quarter of an inch from the target were successful, but beyond that the effects were weakened.

An eight-inch gun was designed and built while these experiments were in progress. The charge to be thrown was to be at least one hundred pounds, the initial velocity approaching that of the eight-inch powder gun, *i. e.*, about fourteen hundred feet per second, and a range of about two miles (the extreme range of the largest movable torpedoes, such as the Sim's electrical torpedoes). The mechanism was such as to enable one man, the person sighting, to train the gun, elevate and fire it, without moving his eye from the sight. The mathematical details of the gun were designed by Mr. Nathaniel Pratt, mechanical engineer of the Babcock & Wilcox Company.

To accomplish the desired result with the pressure fixed upon — two thousand pounds per square inch — it was necessary to make the barrel sixty feet long.

The gun has, thus far, been worked with only one thousand pounds pressure, yet, with an elevation of 35°, a shell carrying a sixty-pound charge has attained a range of two and a quarter miles, and one containing one hundred pounds a range of three thousand yards with 33° elevation.

Having described the machine for projecting a shell charged with high explosives, the question naturally presents itself as to what the effects of the explosion will be. Both confinement and a detonation are required to afford an explosion of the first order. The less sensitive the explosive to shock, the more powerful must be the detonation to produce the maximum results.

Fulminate of mercury appears to be the most powerful detonator, but it is more sensitive to shock than any of the high explosives, so that, if it is desired to throw any of the high explosives, they must be accompanied by a detonator to whose greater sensitiveness the shock of propulsion must be tempered, or premature explosion ensues. Simple heat does not produce explosion, as with gunpowder. The explosives, instead of flashing as gunpowder does, burn comparatively

quietly for some time, and, unless the mass is considerable, there will be no explosion. On the other hand, heating the explosives, even to a comparatively low degree, makes them abnormally sensitive to explosion by concussion.

The relative force of the high explosives appears to be difficult to state, as definite measurements cannot well be made except for small quantities, and I believe that this does not indicate their nature when properly exploded in large quantities.

The most definite values of the relative force of high explosives have been determined by Gen. Abbot, Corps of Engineers, U. S. A., to be as follows, dynamite No. 1 being taken as the standard at 100:

Nitro-glycerine,	81
Compressed or granulated gun-cotton,	87
Rackarock (best formula),	104
Atlas powder (grade A),	100
Forcite gelatine,	133
Explosive gelatine (4 per cent camphor),	117
" " (without camphor),	142

Gen. Abbot concluded, as the result of his experiments, that an instantaneous pressure of sixty-five hundred pounds per square inch can be adopted as the measure of a fatal shock to a first-class ship-of-war. In these experiments eighteen inches of water was used in tamping. [The speaker then described several experiments of dynamite exploded in superficial contact with iron plates, the effects in each case being very slight.] But neither the tamping of eighteen inches of water or explosion in superficial contact can represent the existing conditions when the shell, charged with one hundred pounds of gelatine, comes in contact with the enemy's armoring. It is not proposed to simply send the shell with just sufficient force to place it in superficial contact, but to send it there with a remaining energy, upon striking, of several hundred foot tons, which must doubtless serve as a very effective tamping.

According to a formula deduced from some Scandinavian experiments, one hundred pounds of explosive gelatine will perforate about 6.5 inches of armor. But the decks of the most heavily-armored ships are not over four inches in thickness, and usually less, so that this, certainly, is vulnerable to a shell containing a one-hundred pound

attain a range of two miles in twenty-two seconds, and they can be directed against the enemy much more accurately than appears possible with the others. If it misses the target, the only expenditure is the shell and its charge. Placed, for defence of harbors, within fortifications, they can be brought into use at a time when the enemy's fleet comes to close quarters,— that is, within two miles, the present effective range of the gun. They could be placed on board swift-moving torpedo-boats, which could approach a beleaguering fleet, at dusk or at night, within a mile, and deliver a most damaging fire. Where the enemy has succeeded in removing existing torpedo-obstructions, these machines can shower its pathway with torpedoes which, when the depth is suitable — say fifty to sixty feet or less — can be arranged to explode either directly upon reaching the bottom or at any desired interval. On the other hand, in making an attack in a port, torpedo-boats, armed with the pneumatic gun, could strew the channel, through which the fleet is to advance, with the torpedo-shells, arranged to explode, some, soon after reaching the bottom; others, when fully submerged. These, if dropped at short intervals, would inevitably break up any system of torpedoes which can be planted.

In warding off the attack on a ship by any of the movable torpedoes, if they should be discovered approaching, I can think of nothing which has so many chances of success as the torpedo-shell projected from the pneumatic gun.

A vote of thanks to the speaker brought the meeting to a close.

MEETING 341.

Late Methods of Drilling for Oil and Natural Gas.

BY MR. F. H. NEWELL.

The 341st meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, January 7th, at 8 P. M., Prof. L. M. Norton in the chair.

After the reading of the minutes of the previous meeting, the chairman introduced Mr. F. H. Newell, who read a paper on "Late Methods of Drilling for Oil and Natual Gas."

where exact samples of the rocks passed through are of first importance, cannot compete in cost with the cruder methods in present use. The method in almost universal use is drilling by walking-beam and rope, but it must be remembered that this way of drilling is only applicable in comparatively soft rocks, such as limestones, shales, sandstones, and moderately well-cemented conglomerates, where they are horizontally bedded and unfissured, for the drill, guided largely by its own weight, is easily deflected by inclined bedding, cracks, or planes of weakness, and, once turned from the exact vertical, soon binds and refuses to work, and the hole is straightened only after considerable delay and expense. The art of drilling has grown, by the inventions and discoveries by hundreds of men, from one very simple operation to a business using in special cases an almost innumerable variety of tools, and having large establishments to make its peculiar machinery.

The growth of this specialized industry of making drilling-tools has been accompanied by the adoption of certain standards of sizes of tools and machinery, as also of hole and material inserted, so that at the present time and for some years past all wells are, and have been, drilled of the same size.

Some of the principal considerations which governed the choice of a certain diameter of well are: the smaller the hole the less iron is used in casing; also less material must be removed, thus faster time can be made, the same weight of tools being used. But, on the other hand, the smaller the hole the longer the drill must be to give the necessary weight. It eventually becomes too long for strength or convenience in handling, and, as a compromise between these, the diameter of five and a half inches has been adopted, so that now there are probably over twelve thousand wells of this diameter, ranging in depth from six hundred to two thousand feet.

The principle of ordinary drilling is very simple, the operation being but the employment of machinery to lift and let fall a heavy drill. The drill is suspended from a rope attached to the end of an oscillating walking-beam, at each stroke being turned, so that it may cut a round hole.

When the fine sand and mud, made by the constant pounding of the rock, has accumulated so as to interfere with rapid cutting, the drill is taken out, water is poured into the hole, if not already there,

in place is performed by driving pipe. This pipe is an extra thick lap-weld tube eight inches in diameter; the lower end of the first joint is armed with a steel shoe, shrunk on. It is driven by a log used as a maul, much as piles are driven, guides for which are set up in the derrick, and length after length being screwed on and driven down until bed-rock is reached. To facilitate driving, an eight-inch bit is put inside, drilling out the gravel and dirt, and keeping ahead to break any boulders or hard strata, so that the drive-pipe shall not be deflected.

When the drive-pipe is set, the eight-inch hole is continued below the water-bearing rocks, and casing five and five-eighths inches internal diameter is put in, shutting off the water. Then the ordinary five-and-a-half inch bit is used, and drilling goes on until the oil or gas-bearing rock is reached.

It is customary to torpedo a well as soon as drilled through the oil-bearing sandstones, in order to open fissures in the stone, and thus increase the flow. For this purpose nitro-glycerine is used in quantities up to two hundred quarts, or six hundred and sixty pounds, at a time, a good charge being one hundred quarts, costing, exploded in the well, $1 per quart. It is placed in tin cases four inches in diameter, and about eight feet long, which are lowered, one at a time, the last one carrying a firing-head containing ordinary waterproof percussion-caps. The torpedo is exploded by dropping a weight on the caps, or sometimes by a squib or time-fuse.

The flow of oil following the explosion is allowed to go into the air, that the well may be blown clear of loose stones, pieces of tin and iron, etc.; but immediately after this flow has ceased, the two-inch tubing is put in, and connections made with the tank, to save subsequent flows.

A large number of views were shown of the operations of drilling and shooting the well; of the "cities of tanks" at Olean and other places, belonging to the National Transit Company, whose total storage capacity is 42,000,000 barrels; of burning tanks, etc. These iron storage-tanks, which were described in detail by the speaker, were from eighty-five feet to ninety-five feet in diameter, holding from thirty thousand to thirty-five thousand barrels of oil each (forty-two gallons to a barrel). This was supplemented by remarks on the care of oil and gas wells, storage and transportation of oil, and the present

the stove, and the yellow sodium-flame is their nearest approximation to a hickory fire. Being without smoke, the inside of these fireplaces is frequently white-washed.

The use of natural gas has not been without untoward incidents by way of numerous accidents, most of them of a serious nature; for it is odorless after being conducted a short distance in pipes, and explosive when mixed with between five and thirteen times its volume of air, differing in intensity, being a high explosive at its maximum, of one volume of gas to about 9.5 or 10 volumes of air.

It is very permeating, and, like hydrogen gas, leaks readily through joints perfectly tight against air, oil, or water. The most ingenious expedients have been devised to make tighter pipe-joints, and also conduct leaking gas away from the pipes to the atmosphere.

With these objects in view, it can be considered reasonably safe if the pressure is reduced, by a pressure governor, to less than one and a half pounds to the square inch; all pipes in yards or buildings should be above ground and away from concealed spaces in walls or floors; the fire should be applied before the gas is let on to a stove.

These rules may appear simple, but there will always be instances of their negligent infraction, rendering the matter of natural gas a live issue in underwriting as long as it is used, especially in houses.

Its candle power is eight and one half, and when burned through large burners gives a flaring yellowish flame, with a large blue center.

When carburetted with naphtha the illumination is better, but is exceedingly unsafe in case of leakage.

A vote of thanks was passed to the speaker, and the meeting was adjourned.

MEETING 342.

Transmission of Power by Belting.—An Account of the Work Done on this Subject in the Mechanical Engineering Laboratory.

BY PROF. GAETANO LANZA.

The 342nd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, January 28th, at 8 P. M., Mr. Geo. L. Roberts in the chair.

After the reading of the minutes of the last meeting, and the

The work upon the subject has formed part of the regular laboratory work, and also the subject of two theses,—one by Mr. A. J. Purinton, and the other by Mr. A. L. Merrill.

Before giving an account of this work, and of the results obtained, I will state briefly what has been done by others.

The only experiments of which the writer is aware are the following:—

1°. By Gen. Morin.
2°. By Henry R. Towne, of the Yale & Towne Company.
3°. By Edward Sawyer, of Charlestown, Mass.
4°. By Samuel Webber, of Lawrence.
5°. By Prof. S. W. Holman, of the Mass. Institute of Technology.

(1°.) As to those of Morin, he used a fixed cast-iron drum, over which hung a belt, the ends hanging vertically, and being of equal lengths; these two ends he loaded with equal weights, and then added weight on one side until the belt slipped, and thus determined the two tensions T_1 on the tight side, and T_2 on the loose side. He then determined the co-efficient of friction f, from the formula—

$$f = \frac{\log._e T_1 - \log._e T_2}{\pi}$$

The results obtained by him are as follows:—

New belting on smooth cast-iron, dry, ...	0.284
New belting on smooth cast-iron, wet, ...	0.377
New belting on rough cast-iron, ...	0.281
Old belting on rough cast-iron, ...	0.279

He does not state what was the speed with which the belts slipped when he obtained these results.

(2°.) Mr. Henry R. Towne performed his experiments in the same way, only that he allowed his belts to slip at a speed as nearly 200 feet per minute as he could judge by the eye.

He obtained as a result $f = 0.58$; but he and Mr. Robert Briggs recommend for use two-thirds of this, or $f = 0.42$.

(3°.) Mr. Edward Sawyer, of Charlestown, used also a fixed drum, and performed the experiments in the same way as the other two, with this exception,—that, when he had loaded the heavy side sufficiently to make the belt slip, he then placed additional load on

to the end of the last school year will now be given, but I will first describe the apparatus used and the manner of making the tests.

The slip tests were made entirely on 7-inch, 8-inch, and 10-inch double belts, by loading them with a known power by means of a nicely made Prony brake, on which the power used could be weighed. These tests were made as follows: Placing a fixed load on the brake, readings of counters attached to the driving and driven shafts were taken at definite intervals; and, the diameters of the pulleys being known, the slip of the belt was readily computed. The slip of these belts under ordinary loads was, on an average, about three feet per minute.

Experiments were then made upon a machine driven by power, and specially designed for the purpose, where a pulley was caused to slide under the belt at such a rate of speed as might be desired, and thus the ratio of tensions, and hence the co-efficient of friction under various speeds of slip, was determined.

The machine used for this purpose is shown in fig. 1. By means of the belt *A* and pulley *M*, the worm shaft *B* is set in motion, and, in its turn, drives the worm gear *C*, and hence the shaft *D*, and the pulley *E* which is fixed to the shaft.

FIG. 1.

The belt to be tested hangs over the pulley *E*, one end being attached by the link *F* to the lever *I*, the upward pull on this lever being registered by the dial *H*; at the other end of the belt is attached the scale pan *L*, in which are put weights. The lever *K* is merely a counterweighting lever.

During an experiment the motion is imparted in such a way as to turn the pulley *E* in a right-handed direction, the speed of a point on its circumference being the speed of slip of the pulley under the belt, the right-hand side of the belt being the loose, and the left-hand side the tight, side.

The tension on the loose side is evidently equal to the weight of the scale pan *L* plus the weights in the scale pan, while that on the tight side is read off on the dial *H*.

The average value of this co-efficient, under a speed of slip of three feet per minute, would seem to be, in the light of these tests, about 0.27, corresponding (if the admissible stress per inch of width be taken at 66⅔ lbs.) to the rule that a belt one inch wide must travel 1000 feet per minute to transmit one horse-power.

This requires much wider belts than Briggs' and Towne's rule to take 0.42 for co-efficient of friction; and, as a matter of fact, we never realize in practice, while driving, a slip anywhere near 200 feet per minute, which was the slip used in Mr. Towne's experiments.

I will next give the summaries: —

SUMMARY OF TESTS MADE IN 1883–84.

No. of Experiment.	Kind of Belt.	Side next Pulley.	Nature of Pulley.	Maximum Co-efficient of Friction.	Minimum Co-efficient of Friction.	Humidity.	Speed of Slip, in Feet, per Minute.
1	Old oak-tanned, .	Hair,	Lagged,	0.2700	0.2500	0.39	1.91
2	" " .	"	"	0.2730	0.2570	0.36	"
3	" " .	Flesh,	"	0.2660	0.2460	0.49	"
4	Raw hide, . . .	Hair,	"	1.0420	0.9825	0.44	"
5	" " . . .	Flesh,	"	0.5695	0.5250	0.44	"
6	" " . . .	Hair,	"	0.8800	0.8340	0.44	"
7	New oak-tanned,	"	"	0.2850	0.2620	0.38	"
8	" " .	Flesh,	"	0.2800	0.2640	0.39	"
9	Rubber, ...	–	"	0.3780	0.3450	0.39	"
10	"	–	Cast-iron,	0.3860	–	0.43	1.72
11	New oak-tanned,	Hair,	"	0.1440	–	0.48	1.91
12	" " .	Flesh,	"	0.1710	–	0.48	"
13	Raw hide, . . .	Hair,	"	0.2510	–	0.48	"
14	" " . . .	Flesh,	"	0.2650	–	0.48	"
15	" " . . .	Hair,	"	0.2260	–	0.55	"
16	Old oak-tanned, .	"	"	0.1560	–	0.55	1.95
17	" " .	Flesh,	"	0.1793	–	0.44	1.75

SUMMARY OF SLIP TESTS, 1884–85.

No. of Experiment.	Description of Belt.	Speed of Belt, in Feet, per Minute.	Horse-Power transmitted.	Speed of Slip, in Feet, per Minute.	Remarks.
1	10″ double belt, . .	1311	14.69	14.76	Inclined at about 45° to the horizon. The belt was very slack.
2	" " " . .	1350	11.12	9.64	
3	" " " . .	1365	10.23	7.13	
4	" " " . .	1385	8 31	5.75	
5	" " " . .	1414	5.31	3.57	
6	" " " . .	1411	5.31	3.34	
1	8″ double belt, . .	1537	14.69	10.98	Nearly vertical. The belt was very slack.
2	" " " . .	1586	11.12	7.49	
3	" " " . .	1605	10.23	6.52	
4	" " " . .	1630	8.31	4.61	
5	" " " . .	1666	5.31	2.70	
6	" " " . .	1664	5.31	2.14	
7	10″ double belt, . .	1315	8.88	4.33	The belt was now tightened to about ordinary tightness.
8	" " " . .	1303	11.75	5.41	
9	" " " . .	1298	12.66	3.12	
10	8″ double belt, . .	1597	6.11	1.53	The belt was now tightened to about ordinary tightness.
11	" " " . .	1610	8.21	1.97	
7	" " " . .	1548	8.88	3.44	
12	" " " . .	1593	10.15	4.65	
8	" " " . .	1536	11.75	2.20	
13	" " " . .	1576	12.05	5.14	
9	" " " . .	1528	12.66	4.09	
14	" " " . .	1568	13.99	4.68	
15	" " " . .	1517	15.47	3.71	
10	7″ double belt, . .	1617	6.11	2.70	Horizontal belt. This belt was rather slack.
11	" " " . .	1631	8.21	4.29	
12	" " " . .	1617	10.15	5.70	
13	" " " . .	1600	12.05	6.90	
14	" " " . .	1591	13.99	6.35	
15	" " " . .	1539	15.47	7.94	

It will be seen that when the belts were ordinarily tight the slip would average about three feet per minute.

I will next proceed to give a summary of the tests for determining the co-efficient of friction during 1884–85, a part of which were done as regular laboratory exercises, and a part by Mr. A. L. Merrill for his thesis: —

HAIR SIDE NEXT PULLEY.

Test No.	Speed of Slip, in feet, per Minute.	Ratio of Tensions.	Co-efficient of Friction.
1	2.09	2.22	0.255
2	2.09	2.23	0.255
3	2.09	2.22	0.255
4	2.09	2.23	0.255
5	2.09	2.23	0.255
6	2.09	2.08	0.235
7	2.09	2.02	0.225
8	2.09	2.03	0.225
9	2.09	2.02	0.225
10	2.09	2.03	0.225
Average, .	2.09	2.12	0.240

HAIR SIDE NEXT PULLEY.

Test No.	Speed of Slip, in Feet, per Minute.	Ratio of Tensions.	Co-efficient of Friction.
21	6.84	2.39	0.275
22	6.84	2.41	0.280
23	6.84	2.48	0.290
24	6.84	2.58	0.300
25	6.84	2.67	0.313
26	7.00	2.88	0.337
27	7.00	2.96	0.345
28	7.00	2.83	0.330
29	7.00	2.90	0.339
30	7.00	2.90	0.339
Average, .	6.92	2.64	0.310

HAIR SIDE NEXT PULLEY.

11	2.83	2.34	0.270
12	2.83	2.38	0.275
13	2.83	2.38	0.275
14	2.83	2.39	0.275
15	2.83	2.41	0.280
16	2.38	2.49	0.290
17	2.38	2.49	0.290
18	2.38	2.50	0.291
19	2.38	2.49	0.290
20	2.38	2.51	0.294
Average, .	2.605	2.438	0.283

FLESH SIDE NEXT PULLEY.

31	2.09	1.93	0.210
32	2.09	1.93	0.210
33	2.09	1.92	0.210
34	2.09	1.92	0.210
35	2.09	1.91	0.210
Average, .	2.09	1.92	0.210
36	3.38	2.27	0.260
37	3.38	2.18	0.250
38	3.38	2.16	0.246
39	3.38	2.17	0.248
40	3.38	2.16	0.246
Average, .	3.38	2.19	0.250
41	7.00	3.20	0.370
42	7.00	3.17	0.367
43	7.00	3.11	0.361
44	7.00	3.06	0.357
45	7.00	3.05	0.355
Average, .	7.00	3.12	0.363

No. of Experiment.	Kind of Belt.	Side next Pulley.	Nature of Pulley.	Co-efficient of Friction.	Speed of Slip, in Feet, per Minute.
18	Oak-tanned, ...	Hair, . . .	Cast-iron,	0.776	238.0
19	"	Flesh, . . .	"	0.45	238.0
20	"	Hair, . . .	"	0.82	210.0
21	"	Flesh, . . .	"	0.51	210.0
22	"	" . . .	"	0.37	15.4
23	"	Hair, . . .	"	0.30	15.4
24	"	" . . .	"	0.33	15.0
25	"	" . . .	"	0.33	15.0
26	"	Flesh, . . .	"	0.36	15.0
27	"	Hair, . . .	"	0.34	16.9
28	"	Flesh, . . .	"	0.42	16.9
29	Raw hide, ...	Hair, . . .	"	0.36	14.9
30	" "	Flesh, . . .	"	0.38	14.9
31	" "	Hair, . . .	"	0.33	15.1
32	" "	Flesh, . . .	"	0.45	15.1
33	" "	Hair, . . .	"	0.38	13.9
34	" "	Flesh, . . .	"	0.45	13.9
35	" "	Hair, . . .	"	0.42	14.9
36	" "	Flesh, . . .	"	0.52	14.9
37	" "	" . . .	"	0.74	12.8
38	" "	" . . .	"	0.67	12.8
39	Oak-tanned, ...	Hair, . . .	"	0.43	12.7
40	"	" . . .	"	0.37	12.7
41	"	" . . .	"	0.32	12.7
42	"	Flesh, . . .	"	0.37	12.4
43	"	" . . .	"	0.31	12.4
44	"	" . . .	"	0.32	12.4
45	Raw hide, ...	" . . .	"	0.60	12.5
46	" "	" . . .	"	0.58	12.5
47	" "	" . . .	"	0.57	12.5

I will give next the values of $\frac{T_1}{T_2}$ correspondiug to each of these co-efficients of friction, with 180° arc of contact:—

For $f = .17$ $\frac{T_1}{T_2} = 1.708$

" $= .27$ $\frac{T_1}{T_2} = 2.335$

" $= .42$ $\frac{T_1}{T_2} = 3.776$

It may be well that I should, before going farther, explain how to use the co-efficient of friction, or the ratio of the tensions in determining the proper width of belt to transmit a given power at a given speed. When we know the foot pounds of work to be done per minute, and the feet per minute traveled by the belt, we obtain by division the effective pull, or the difference of the tensions ($T_1 - T_2$). Thus if we are to transmit 30 H. P. at a belt travel of 1500 feet per minute, we should have —

$$T_1 - T_2 = \frac{30\ (33{,}000)}{1500} = 660 \text{ lbs.} \qquad (1)$$

Now, as soon as we know the ratio $\frac{T_1}{T_2}$ we can at once obtain the value of T_1, and as soon as T_1 is known, we determine the width of belt by dividing T_1 by the greatest admissible stress per inch of width. Thus we should obtain in this case —

For $f = 0.17$	$T_1 = 1592$ lbs.
" $= 0.27$	$T_1 = 1154$ "
" $= 0.42$	$T_1 = 898$ "

Now, knowing the tension required on the tight side, we determine the width of belt required as soon as we know the greatest allowable tension per inch of width. This is given by Briggs and Towne as 66⅔ lbs. = ⅓ (200) lbs., 200 lbs. being a fair average value of the breaking strength per inch of width of a laced belt, breaking through the lace-holes.

If we assume this value for the greatest allowable tension per inch of width, we obtain —

For $f = 0.17$,	width required = 24.″ inches.
" $= 0.27$,	" " = 17.″3 "
" $= 0.42$,	" " = 13.″4 "

The following table will now be intelligible, exhibiting as it does the results thus far obtained under a variety of aspects: —

	Co-efficient of Friction.	T_1 required to transmit 1 H.P. at 1000 Ft. per Minute, in Lbs.	T_2 corresponding, in Lbs.	$T_1 + T_2$ corresponding, in Lbs.	T_1 required to transmit 1 H. P. at 1500 Ft. per Minute, in Lbs.	T_2 corresponding, in Lbs.	$T_1 + T_2$ corresponding, in Lbs.
Morin, ...	0.28	55.2	22.2	77.4	36.8	14.8	51.6
Towne (experiments)	0.58	39.3	6.3	45.6	26.2	4.2	30.4
Towne (given to be used), ...	0.42	45.0	12.0	57.0	30.0	8.0	38.0
Sawyer, ...	0.12 to 0.17	105.0 to 79.6	72.1 to 46.6	177.0 to 126.2	70.0 to 53.0	48.0 to 31.0	118.0 to 84.0
M. E. Lab., with slip of 3 feet per minute, ...	0.27	57.8	24.8	82.6	38.5	16.5	55.0

For different arcs of contact from 180° the ratio of tensions would be different, being given by the formula $\frac{T_1}{T_2} = e^{f\theta}$.

It would seem reasonable that, with a belt travel of about 1500 feet per minute, which is about the speed of the belts used in making the slip tests, the speed of slip should not be more than about three or four feet per minute; and this would necessitate a co-efficient of friction of about 0.27, which means that the belt should have a strain of 55 pounds per horse-power transmitted. This is the value of the co-efficient of friction deduced as an average by Mr. Merrill in the tests that he made for his thesis. It is also evident that, if we use a higher co-efficient, as 0.42, we must, in order to realize it, have a strain upon the belt of only 38 pounds per horse-power transmitted; but then we should have a speed of slip much larger than would be suitable to use in practice; and that, if we determine the width of the belt on the basis of 38 pounds, and then strain it more, we are no longer keeping within the limits of safety intended.

While the work described above would seem to throw a great deal of light upon the problem of belting, there are two objections that might be theoretically raised to this form of experiment, which objections can only be refuted by another form of experiment. These objections are as follows: —

and being merely used as a safety-stop. The planks *F F* are, therefore, free to turn up and down about the hinges *G G*. The levers *M M* are merely counterweighting levers.

The desired tension is put upon the vertical belts after they are in position by means of the turn-buckles in the links *H H*, which are attached to the levers *K K*, and thence to the scale-beams *L L*. The weights shown on the scale-beams are, therefore, the sums of the tensions, or the values of $T_1 + T_2$.

Besides this, a revolution-counter is attached to the shaft *A*, and another to the shaft *E*, and hence we readily obtain the slip of each belt.

Prof. Peabody, Prof. Schwamb, and myself have all had a hand in getting up this apparatus for the laboratory.

I have already explained how, when the power transmitted and the speed are known, we can obtain $T_1 - T_2$, and have explained that, when using the friction theory, we use the ratio $\frac{T_1}{T_2}$ to determine T_1 and T_2, and hence the width of belt required.

In this new form of experiment we determine instead $T_1 + T_2$ by actually weighing it on a scale; hence we obtain the exact values of T_1 and T_2 without any assumptions whatever, and we are, therefore, enabled to answer the following questions: —

1°. In order to transmit a given power at a given speed of belt, what is the least value of $T_1 + T_2$ with which we can succeed to drive at all, without having the belt slip off? What is the speed of slip we obtain under these conditions, and what the values of T_1 and T_2?

2°. If a given power is to be transmitted with a given speed, and the speed of slip is not to exceed a given quantity, what is the value of $T_1 + T_2$ required for the purpose? and what are T_1 and T_2?

Having answered these questions, the question of width of belt is to be determined by so fixing it that it shall be able to bear the required value of T_1 without injury, and without losing its tightness. The following table gives a summary of the results thus far obtained:

While there are more or less irregularities in these tests, for some of which the reason is not yet clear, nevertheless a perusal of the table will, I think, make it plain that, in order to obtain fair running, we need to use a value of $T_1 + T_2$ at least as great as 55 lbs. per horse-power. and this corresponds to a co-efficient of friction of about 0.27. It is also plain, it seems to me, that a co-efficient of friction, 0.42, corresponding to $T_1 + T_2 = 38$, is entirely wrong, and is never realized in practice with fair running.

Now, this work with the belting gives us the amount that it is necessary to strain a belt in order to carry a certain power at a certain speed, with no more than a certain amount of slip; and there remain two things to be attended to: 1°. Our belts ought to be put on in practice with a known tension. 2°. The criterion that determines the proper width should be the least of the two following quantities, viz., the breaking strength divided by a suitable factor of safety, or the greatest tension which the belt can hold for a reasonable length of time.

It has thus far been the first that has been accepted as the proper criterion, and it is possible that this may be a reasonable thing to do with laced belts, but with a glued belt, such as any of our double belts, it is the latter that should be used. In this regard there never have been any figures whatever determined, and we propose to make experiments upon it, running the belting machine for a week at a time. and noting how the load drops off.

Next, in regard to anomalies: it will be noticed that the west belt slips almost always more than the east. The reason of this has not yet been ascertained; but the probability is that the results with the east belt are the most reliable.

Another question of interest is that the value $T_1 + T_2$ which is measured while the belt is running decreases as soon as the load is let off, if the load is at all considerable.

eers a furnace designed to melt considerable quantities of such excessively refractory metals as platinum, iridium, and steel. It differed from the furnace used by Deville in having a carbon rod for one electrode, and the metal contained in a graphite crucible as the other electrode. The crucible was surrounded on the *outside* by fine charcoal. Inside an arc was formed, which was adjusted by proper mechanism. He explained that he was led to undertake experiments of this nature by the consideration that a good steam-engine converts fifteen per cent of the energy residing in coal into mechanical effect; while a good dynamo electric-machine is capable of converting eighty per cent of that mechanical energy into electrical energy. If the latter could be expended without loss within an electric furnace, it would doubtless far exceed in economy that of the air furnaces still largely used in Sheffield. Other important work, and his death two years later, probably prevented the further development of this furnace.

A year later Faure took out patents for an electric furnace designed for the reduction of sodium and potassium. At this time the science of chemistry had quite reached the point where it was ready to say that the oxides of such metals as aluminum, calcium, magnesium, and metalloids, as boron and silicon, were not susceptible of reduction with carbon as the reducing agent. It may be from this cause that he did not cover a broader field, or from some imperfection in his furnace, that he did not put into execution the splendid idea of manufacturing by a cheaper process sodium and potassium.

I will now continue with a description of the furnace. It is simple in construction, being what might be called a rectangular box, one foot wide, five feet long inside measurement, and fifteen inches deep, and made of fire-brick. From the opposite ends, through pipes, the two electrodes and holders pass. The electrodes are immense electric-light carbons, three inches in diameter, and thirty inches long. The ends are placed within a few inches of each other, in the center of the furnace. The pipes contain packing boxes which prevent the air from entering into the interior. The furnace now operated at the main works of the Brush Electric Company, in Cleveland, is connected with the largest dynamo ever made by that company. It produces about 70,000 watts of current, or about ninety electrical horse-power, as its average work. In this circuit, between the furnace

Now that the furnace is charged, and the cover luted down, we are ready to start, and observe what takes place. The ends of the electrodes were in the beginning placed close together, and from this cause the internal resistance of the furnace may be too low for the dynamo, and cause a short-circuit. We, therefore, throw sufficient resistance within the circuit, by means of the resistance box, to make it safe to start the dynamo. This being done, an attendant gradually takes the resistance of the box out of the circuit, and, by watching the ammeter, and now and then moving one of the electrodes out a trifle, he is enabled to prevent undue short-circuiting in the beginning of the operation. In about ten minutes the copper between the electrodes has become melted, and the latter are moved far enough apart so that the current becomes steady. The current is now allowed to increase till we are drawing from the dynamo about thirteen hundred amperes, driven by fifty volts. Carbonic-oxide gas has already commenced escaping through the two orifices in the top, and there it burns to carbonic-acid gas, forming two white plumes of flame. By slight movements outward of the electrodes during the coming five hours, the internal resistance of the furnace is kept constant, and at the same time all the different parts of the charge are brought in turn into the zone of reduction. At the close of the run, we shut the furnace down by placing a resistance in the box, and then switching the current into another furnace, which has been charged in a like manner.

During five hours there has been, we might say, pumped into the furnace ninety electrical horse-power. By Jouls's equivalent, when this power is changed to heat, it equals one million one hundred and fifty-four thousand Fahrenheit heat units, or sufficient heat, if it were devoted to heating the fifty pounds of copper alone contained within the furnace, to raise it to a temperature of two hundred and forty-two thousand degrees, were such a thing possible. During the beginning of the operation the copper first melted in the center of the furnace. There was no escape for the heat that was continually generated. The temperature increased till the refractory corundum melted, and, being surrounded on all sides by carbon, gave up its oxygen, and thereby complies with Berthollet's law. The heat of the union of the oxygen liberated from the aluminum uniting with the sesquioxide carbon has certainly aided in the economy of the process.

hand a beautiful means of future automatic regulation of the electrodes, of the feeding of the charge, of the working of the dynamo, and of the driving of machinery, so that all parts may be made to work in perfect harmony. Within the coming year the Cowles' Electric Smelting and Aluminum Company will have facilities to concentrate within one furnace the energy of twelve hundred horsepower, or nearly that of the great Corliss engine, which furnished the power for Machinery Hall at the Centennial ten years ago. With a larger furnace there is no reason why it should not be made to run continuously like the ordinary blast furnace.

The temperature attainable within the furnace is only limited by the fusion point of carbon; as yet we have not reached this limit. The charcoal is easily changed to graphite, but so far it has always retained its woody structure. A run, carefully made with this fusion in view, would be intensely interesting, as it would probably solve the question as to whether the diamond is a product of fusion, or a product of crystallization from a solution. The fusion of the corundum frequently gives us minute crystals of the ruby and sapphire.

Pure white sand is not only made to melt, but is easily reduced to silicon. Here we have a mass of minute crystals of silicon, that came from a fire brick being placed within the furnace, and too near the center of heat. The other elements that were present seem to have volatilized, leaving nothing but the silicon behind.

Boron, sodium, potassium, calcium, magnesium, chromium, and titanium have all been reduced in the furnace. It is safe to say that no metallic oxide can resist the intense reducing forces that are here brought to bear upon it. To go further into the great chemical possibilities of electric smelting would take too much time.

In the operation of the furnace, copper was used to gather the aluminum together, and to prevent its formation into carburette of aluminum, or into the amorphus powder. The copper acts somewhat as a condenser to the metallic fumes of aluminum liberated. In place of the copper, any non-volatile metal may be used as a condenser, to unite with any metal we may desire to reduce; provided. of course, the two metals are of such a nature that they will alloy with each other at this high temperature. In this way aluminum may be produced and obtained, alloyed with iron, nickel, silver, tin, or cobalt. We have made alloys containing fifty per cent of aluminum, and fifty

a strength greater than cast iron by one half. Pure, it can be rolled into sheets or drawn into the finest wire. Its electrical conductivity is sixty-four, copper being one hundred. Taking its specific gravity into consideration, we find it is two and one-fifth times as efficient as copper, and about twenty times as efficient as iron as an electrical conductor. In other words, aluminum wire at one dollar and twenty cents a pound would be as cheap as iron wire at six cents for electrical purposes, and have the advantage of using but one-twentieth the weight. In alloying with other metals it seems to impart in almost every case new and valuable properties to the resultant alloy. Here is a sample of the finest grade of aluminum bronze. [Sample shown.] It contains about eight and one-half per cent of aluminum and one per cent of silicon. Tests have shown that silicon increases its strength, and does not interfere with its fine color or luster. Cast samples have shown as high as one hundred and seventeen thousand pounds tensile strength to the square inch. In making this bronze, the white metal, rich in aluminum, is first melted, and then the requisite copper added to it till a sample can be taken from the crucible which shall show a test of ninety thousand pounds or over. Unlike ordinary brass or bronze, it will stand remelting or long-continued heat without marked deterioration. This was proved by melting one hundred pounds in a crucible. After it was melted a test was made which showed ninety-five thousand pounds tensile strength, and six per cent elongation. The metal was now kept at an intense heat for four and one-half hours. At the end of that time it was again tested, and showed eighty-three thousand pounds tensile strength, and eleven per cent elongation. No appreciable loss could be detected in the weight. In hardness it does not quite equal untempered tool steel, yet it is so hard that a polished surface is not easily scratched. As an anti-frictional metal it is said to be unsurpassed. Its fine color and permanent luster have enabled it to find a ready use at its past high price for ornamental articles, and its great strength has led to its use in many places where strength and beauty were desired. It has been highly recommended for heavy artillery. Its high price in the past seems to have been the only cause that has precluded its use in guns, propeller wheels, and a thousand and one places where great strength is desired without the work of forging steel. At a red heat aluminum bronze is malleable, and, unlike copper or ordinary bronzes,

MEETING 344.

The Transmission of Steam.

BY MR. CHARLES E. EMERY.

The 344th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Feb. 25th, at 8 P. M., Prof. Gaetano Lanza in the chair.

After the reading of the minutes of the last meeting, the chairman introduced Mr. Charles E. Emery, of New York, who read a paper on "The Transmission of Steam."

The lecturer stated that the nature of the difficulties encountered in transmitting steam for a considerable distance are not generally understood. Condensation necessarily takes place, as is expected, but non-conductors may be applied to reduce this loss to so small a proportion of the carrying capacity of the pipes that it will not form a serious disadvantage in a mere commercial sense. The problem may be called difficult on account of the number of principles involved, and the mass of engineering and mechanical details required to apply the principles correctly and successfully. Condensation is but one of the many conditions to be provided for, and, in some respects, an embarrassing one, but it can be satisfactorily dealt with much more readily than several others.

The expression, "A District Steam System," is now accepted as referring to a plant in which steam, generated in a central station, is distributed through under-ground pipes laid in the public streets, so that the steam may be taken at will by consumers "on tap," so to speak, the same as gas and water. Such a plant is, in some respects, similar to, and at first sight would appear to be only an enlargement of, the method of distributing steam from a central point to the buildings of a large factory or public institution. In fact, however, the conditions encountered in putting pipes in streets already full of under-ground obstructions, such as other pipes, vaults, sewers, etc., in such a manner that consumers can be accommodated when and where desired, involve many more difficulties, and require many modifications in detail, compared with a system where all the property is under one control,

placed in bulk. The result of this method of covering has been that with nearly five miles of large pipe, also about seven miles of smaller pipes used as services, all under steam continuously days, nights, and Sundays, there is required but one hundred and fifty horse-power, each of thirty pounds of water per hour, to supply the condensation in the mains. The mains vary from sixteen inches in diameter to six inches, and the services are mostly three inches in diameter. This loss is so small, as has been previously stated, that it does not affect seriously the commercial problem of the transmission of steam. The water of condensation, however, though limited in quantity, must be properly provided for. If in all cases steam could be transmitted at slow velocity in a large pipe, graded so as to have a slight descent *away from* the source of supply, the water in the steam would separate by gravity, and trickle along the bottom of the pipe, the size of the stream of water gradually increasing until means were provided to permit its escape. By taking the steam from the top of such a pipe, and arranging to blow out the water at intervals from the bottom, the length of the pipe could be continued indefinitely, no inconveniences would result except the loss of pressure due to the distance, and the steam at any point would be as dry as though it came from the boiler direct. This ideal state of facts is accomplished as nearly as possible in practice. Steam must, however, at times be carried up a slope instead of down, and frequently the pipes must have undulating grades to correspond substantially with those of the surface of the ground. When the movement is up a slope, the water of condensation is to a greater or less extent entrained by the current of steam, which is particularly the case when the steam is moving at a high velocity. In practice, the up grades in the direction the steam is transmitted are made as sharp and as short as possible; and beyond the summits, the down grades, in which there is a natural separation of the steam and water, are made easy and long. This desirable arrangement cannot always be carried out; the street obstructions are frequently so arranged that the pipe can only be laid in undulating grades corresponding more or less to those of the surface. In all cases arrangements are made to trap out the water of condensation at the bottom of every dip of the pipe, so that the current of steam passing onward and upward has no more water to contend with than is condensed in the portion of the pipe to be passed over. The water

teenth of an inch thick, corrugated concentrically, and supported on radial backing-plates, which prevented the diaphragm from being distended to rupture by the pressure. A double variator has two diaphragms, and provides for expansion from two fixed points on either side, fifty feet away. The single variator has but one diaphragm. The services are taken from the bodies of these variators. The outlets are provided with flanges, but are plugged in the first instance, the plugs being removed as required with steam pressure in the mains by bolting a valve to the flange and removing the plug through it by means of a special tool. The stems of the valves are extended nearly to the surface of the street, and may be operated through suitable openings in castings placed between the paving-stones. At regular intervals of about fifty feet the pipes are connected by means of ball-joints, which enables their direction to be changed slightly, and takes out all strain. Both the ball and plain flanged joints are made tight by the use of gaskets of thin copper corrugated annularly, which squeeze into every irregularity of the surface, and make absolutely tight work, even without the use of paint or putty. Pipes of six inches in diameter, or less, are screwed into the fittings. Larger pipes, of which some have been used as large as sixteen inches, are expanded into the flanges and fittings. The ends of the pipes abut against shoulders, and the faces against which the expansion takes place are slightly dovetailed. The variators are provided with flange-boxes which cover the connecting flanges, and terminate in cylinders of metal, which are built in the brick work surrounding the variators. The bodies of the crosses and tees are made globular to better resist the strains to which they are subjected. Wherever a valve is placed in a pipe, or a line is terminated, heavy anchorage castings are abutted against the flanges of the pipes, and masonry built against castings with wings well spread out to engage with as much of the surrounding soil as possible, and thereby hold the pipes and fittings rigidly in position. Two lines of mains are run, one for steam, the other for the return-water of condensation. Generally, the latter main is laid lower than the other, so that the outlets of the two mains will pass each other. On Fifth Avenue, where there is rock excavation, with large water-pipes lying at one side, the bottoms of both mains are put on a level, and the side outlets take out below the level of the mains through what is called a drop-cross.

however, steam be blown in below the surface of the water, a bubble will be formed, which will increase in size until the surface becomes sufficiently extended to condense the steam more rapidly than it can enter, when a partial vacuum will be created, the bubble will collapse, and the water flowing in from all sides at high velocity will meet with a blow, forming what is called a water-ram. In blowing steam into a large vessel, these explosions occur in the middle of the mass, and create simply a series of sharp noises. If, however, steam be blown into a large inclined pipe full of water, it will rise by difference of gravity to the top of the pipe, forming a bubble as previously stated, and, when condensation takes place, the water below the bubble will rush up to fill the vacuum, giving a blow directly against the side of the pipe. As the water still further recedes, the bubble will get larger, and move farther and farther up the pipe, the blow each time increasing in intensity, for the reason that the steam has passed a larger mass of water which is forced forward by the incoming steam to fill the vacuum. The maximum effect generally takes place at a "dead end," as it is called, or where the end of the pipe is closed. Even if the water does not originally extend to the "dead end," if the pipe near it be once filled with steam which has bubbled through water on its way to that point, there may be sufficient cold metal to condense it, so that collapse will take place on the same principle as before, and the whole mass of water in the pipe be driven by the incoming current of steam against the end, sometimes with tremendous force, the effect being to cause leaks, and sometimes rupture the pipe or break out the end connections.

He explained that water-rams may be prevented either by draining the pipes or by opening one end of the pipe and introducing steam quickly and in large volume at the other, thus forcing the water ahead of the steam so rapidly that bubbles cannot be formed, and rams not take place. The latter plan requires nerve and judgment, so an ordinary workman cannot be trusted to undertake it.

In concluding, the lecturer stated that there is a field for another lecture in a popular view of the question relating to the uses to which steam from the streets can be put, and the advantages of this method of supply. It will be understood that steam-engines of all kinds and sizes, in any location, from cellar to garret, can be operated to drive shops, furnish electric light, pump water, and the like, and that heat-

efforts to advance still further the comforts and civilization of mankind.

The lecture was illustrated by numerous views, thrown on the screen, of the variators, meters, traps, valves, crosses, tees, special fittings, etc.

A vote of thanks to the speaker for his very instructive paper brought the meeting to a close.

MEETING 345.

The Roadways of New Mexico.

BY HON. CLARENCE PULLEN.

The 345th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, March 11th, at 8 P. M., Prof. Geo. L. Vose in the chair.

After reading the minutes of the previous meeting, the chairman introduced Hon. Clarence Pullen, ex-Surveyor-General of New Mexico, who read a paper on "The Roadways of New Mexico."

Mr. PULLEN said: In order to speak understandingly of the roadways of New Mexico, it is necessary first to describe some of the natural features and present conditions of that interesting but generally little-known part of the United States. New Mexico, which was successively an ultramarine province of the Spanish crown, a State of the Mexican republic, and a territory of the United States, lies between north latitude 31° 21′ and 37°, and between west longitude 103° and 109°. Its shape is generally rectangular, its average length north and south being 362 miles, and its width 335 miles. Its hight ranges in round numbers from 4000 feet to 12,000 feet above the sea level. One-third of its area is composed of a series of level *mesas*, or table lands, beginning at the east slope of the Rocky Mountains, and breaking precipitously, one down to the other, to the plains of Texas. The west two-thirds of New Mexico lies upon the ridge of the continent,

encounter, even at the sacrifice of directness, a watering place at least once in an average day's journey.

The position of streams, springs, and wells is the primary element in the determination of the roadways of New Mexico.

The traveled ways of New Mexican towns represent three different races and civilizations. Those of the Aztec, or Pueblo Indian, cities are mere haphazard paths or openings, left for convenience as successive houses were built, but with no reference to a pre-arranged method; or in the cities of more antique type, as Taos or Zuñi, narrow alleys or passages between houses so closely united as to be practically one vast building. The Pueblo Indian travels on foot, and transports all freight on the small pack animals of the country, and so needs none of the more extended facilities rendered necessary by the use of vehicles.

The Mexican towns, which greatly predominate in the territory, are built in the usual Spanish fashion, the houses fronting solidly upon a plaza, or public square, from each corner of which two narrow streets lead out into the open country. But little attention is given to the building or mending of roads, and the streets and plaza are usually in the shape to which they have been reduced by the action of wheels and foot travel upon the natural surface, or by the washing of rains. The streets leading from the plaza meander in conformity with the configuration of the ground, and beyond the houses of the town are mere mountain or prairie trails. The houses of a Mexican town are one story in hight, and have verandas facing the streets or plaza. The walls are of great thickness, and in the older houses extend above the flat roof, forming a parapet available, should necessity arise, in the defence of the establishment. The almost invariable building material in New Mexico is adobe, a tough clay, which, mixed with grass or straw, molded into large bricks and dried in the sun, makes, in so dry a climate, an available and enduring structure. The walls of corrals, gardens, and cultivated fields are made of adobe. The larger Mexican houses are built about a court, called the *placeta*, often of considerable area, and upon which open inner doors, windows, and verandas. This court is entered from the street by a passage or archway, closed by double gates. The whole arrangement of the establishments of the wealthier Mexicans illustrates the Spanish-

observation and vantage, but are so located as to leave the travelers thereon as much as possible in concealment. These paths are indicative of the predatory character of their makers, and are carefully scrutinized in times of Indian troubles.

In 1536 Cabeza de Vaca, who had been shipwrecked nine years before on the coast of Florida, entered New Mexico on the east, and traversed the southern part of the present territory. In 1541 Francisco Vasquez de Coronado, the governor of New Galicia, made an expedition into New Mexico with four hundred Spanish and eight hundred Indian soldiers. He went north to the Indian city which was on the present site of Santa Fé, and then, in quest of the "seven cities of Cibola," and their reputed inestimable riches, he crossed the plains to the eastward, and actually traversed the present State of Kansas. In the rooms of the Historical Society of Kansas is shown a map of his route, which is practically identical with the location of that famous highway of prairie commerce known during the present century as the Santa Fé Trail.

Two great trails have, during three centuries, connected Santa Fé, in New Mexico, with Mexico, one leading down the Rio Grande across the Jornada del Muerto (Journey of Death) and south to the city of Mexico, the other leaving the Rio Grande and lying southwest across the plains and mountains through the Apache Pass, thence to Guaymas, in Sonora. The journey to and from the City of Mexico from Santa Fé formerly occupied five months.

The Santa Fé Trail from Independence, Mo., to Santa Fé may be considered to have been fairly established in 1822, when a party of thirty-five men, with pack horses, carrying $15,000 worth of goods from St. Louis, Mo., went over it to the capital of New Mexico. In succeeding years wagons took the place of pack animals. Thereafter, the tide of a great commerce never forsook this highway until it was supplanted by the road of the iron rails, and it was strung from one end to the other with the white-topped wagons of freighters. It is now much used as a wagon road, but its great commercial importance is a thing of the past. Where this trail crosses the Raton Mountains, "Uncle Dick" Wooton, an old frontiersman, and companion of Kit Carson, built a turnpike road, and charged all passing wagons a dollar apiece, which yielded him for many years a princely revenue.

The first railroad to enter New Mexico was the Atchison, Topeka,

homes, in our workshops, in the halls of legislation, and even in the temples of the Infinite. With an importunity that makes no refusal, it demands and will have answer. What shall the answer be? What shall the manner of the answer be? Shall the best answer we have to give be strikes and lock-outs? Shall the manner of the answer be "with confused noise and garments rolled in blood"?

The particular phase of this problem to which I desire to direct your attention, which is also in its practical relations the most important one, is the constantly recurring differences between employers and employed, and the best method not only of settling them but of preventing their occurrence.

While the present relations of employer and employed continue, differences will of necessity arise between them. At many points their interests and opinions diverge. These differences will at times grow into disputes, and may result in the industrial strife that is in strikes and lock-outs. Just here let me emphasize the fact, too often overlooked or forgotten, that strikes and lock-outs are not the beginnings of industrial strife. Its source is in these differences, and industrial peace, with all its blessings, is best secured not by settling strikes and lock-outs when they arise, but by preventing or settling these differences between employer and employed before they have time to grow into strikes.

To discover the best method of settling these differences, and of preventing them from becoming disputes, is an imperative duty. To settle these disputes, if unfortunately they arise, without the massing of forces and the shock of conflict, without driving strong men to sit hollow-eyed and despairing, and hounding women and little children into the very shadow of death, is demanded for our own safety and for the stability and perpetuity of our institutions.

And may I suggest that the search for this method should be without any anxiety to preserve intact what have come to be regarded as economic laws. Of the authority of many of these laws, and of the obligations they impose upon men, there are grave doubts. There are higher objects in life than the preservation of what, at best, are only "expressions of an observed tendency in human affairs." There are no economic laws that are eternal and commanding. On the contrary, there are forces in the domain of industry that regulate and modify, and even at times abrogate, these so-called economic laws.

well-nigh innumerable, they readily group themselves into three classes: —

First. Differences as to future contracts.

Second. Disagreements as to existing contracts.

Third. Quarrels over some "matter of sentiment."

By contracts are meant not only formal agreements, but customs of the trade or shop, or methods of work or administration that have the force of contracts. Under quarrels over "matters of sentiment" would be included quarrels growing out of the wounded self-respect of the parties to these differences, or involving their personal relations and ideas of fairness, justice, personal rights, or good faith.

These three classes of differences have distinctly marked characteristics. The second relates to work actually done and rights that have accrued; the first to work to be done and the basis on which it is to be performed, and involves, if I may be allowed the expression, the fractional right of each party to production in the results of their joint efforts. Now, it is evident that a method that may be adapted to the settlement of one of these two classes may utterly fail when applied to the other, and may be still less adapted to the third class, which involves no property rights at all, but only "questions of sentiment" that are not amenable to the rules or considerations that apply to property.

While it thus appears that there are marked distinctions between labor differences, it will be found that the chief causes of these differences are questions as to rates of wages. It is here that the interests of employer and employed begin to diverge, and it is concerning these questions that differences most frequently result in labor contests. It will also be found that many questions which are not primarily wages disputes have a direct bearing upon rates of wages, and are important only because of such bearing.

In an inquiry into the strikes and lock-outs of 1880, which I made for the Tenth Census, out of a total of 813 labor contests investigated, 582, or 71.59 per cent were caused by differences as to rates of wages. Of these 582 contests 86 per cent were for advances, and but 14 per cent against reductions.

So also it will be found that these wages disputes, with hardly an exception, have regard to the future. Fully 90 per cent of these

But, in addition to this inability arising out of the nature of the questions submitted for decision, such competition as this method contemplates is, under existing conditions, at times neither possible nor desirable. There are menaces to the stability of society in its prevalence. It is the method of contest, not of judgment and reason. There are obstacles in the way of its action that grow out of all the relations which the members of industrial society hold to each other. There are forces in this society which at times are more powerful than the assumed individual impulse towards the best market, which regulate and modify and even thwart competition.

Further, the tendency of competition, acting without restraint or guidance, is not to right economic wrongs or establish justice. I need hardly say that the end sought is not simply a solution of these vexed questions, but one that shall be just and equitable. Such a solution is not, as a rule, the result of the dealings between an individual employer and an individual workman. Realizing this, and also that competition is destructive, and that the highest welfare of a people is not always in buying its calico cheap, labor is refusing to deal as individuals with its employers, and is insisting upon its right of combination, and that these combinations shall have a part in fixing the rewards of labor, and the conditions upon which work shall be done. I need scarcely suggest that its demands are being complied with.

As to the second method,—legislative enactments,—it is now generally conceded that legislation relative to labor questions of the iniquitous character that prevailed in England for four centuries and a half—from, say, 1349 to 1802—is a failure. This legislation sought chiefly to regulate or fix wages by act of parliament, or the decisions of magistrates, and to prevent combinations of labor. The experience of these centuries has taught not only the injustice and injury to all classes of such attempts, but the futility as well.

The failure of this legislation, however, cannot fairly be urged as conclusive against all legislative interference with labor questions. There has grown up in the last few years, especially in England, a body of legislation of a very different character from that referred to, and treating of subjects with which legislation can legitimately deal. Among these laws are those regulating the hours and conditions of employment in certain dangerous and unhealthy trades, as mining and

between employer and employed, I have yet to learn of any advocate of the system, except as a last resort, and when other methods fail. I know that the history of strikes — and even recent ones — shows that folly and passion, not to say baser motives, have guided men both into and through these contests, but it still holds true that neither empoyer nor employed deliberately advocates this method as the ruling one. The leading trades unions incorporated into their fundamental law their decided objections to strikes, and decline to enter upon them or to permit their executive authority to recognize as valid those that may be undertaken by individuals until other methods have been tried and exhausted. These men know by bitter experience the brood of sorrows that accompany and follow these strikes. They have brought hunger, misery, debt; have broken up homes, severed long associations, forced trade to other localities, and driven men and women into the very shadow of death; and yet men, knowing that all of these possibilities are before them, will deliberately enter upon strikes, will cheerfully bear all these privations, and, what is more remarkable still, in many instances the wives of the strikers, upon whom the misery falls with the most crushing force, will be the most determined in their prosecution. It would seem that there must be some reason for this, and it will be found that strikes are not wholly wrong, and that even unsuccessful ones are in many ways advantageous to the strikers. Labor has had to fight for every advantage it has gained, and, though it is often defeated in its struggles that are called strikes, it has not only learned in these contests how better to wage future battles, but has so impressed employers with its strength that it has made them shy of encountering antagonists constantly growing more formidable.

They have also made employers more willing to examine into the causes of complaint, and to meet their employés in a spirit of fairness when differences arise. The most hopeful indication of modern industrial society is the great increase of mutual respect and good-will between employer and employed, as well as a greater regard on the part of each for the rights of the other. To this result strikes have contributed in no small degree. They have also asserted the right of combined labor to deal with combined capital, and have denied the claim that the true labor market was found in the "hig-

gence, information, and judgment of both employer and employed, standing at different sources of information, and looking at these questions from different points of view. This method takes cognizance of existing conditions; recognizes the perfect equality of employer and employed; commits the prevention and settlement of these differences to the reason and judgment of both, not to the selfish impulses of one; refuses to recognize force; does away with the necessity and excuse for strikes and lock-outs; permits due weight to be given to economical forces, and due consideration to any action their presence and power demand; furnishes the nearest approach to a free, open, labor market that has yet been established; in a word, it meets better than any method yet proposed the conditions necessary to a satisfactory and intelligent discussion and settlement of these questions, and offers far greater surety that justice will be done and equity and peace established than does any method that relies upon blind, unreasoning, undiscriminating law or force.

The remainder of the time at my disposal will be given to a discussion of this system.

Though the terms "arbitration" and "conciliation" are jointly used to name the system of dealing with labor differences by boards or committees made up of both employers and employed, these words by no means represent the same thing. "Conciliation" is properly applied to attempts to settle or prevent labor differences by conferences between the parties in interest, or their authorized representatives, these conferences having no power to reach a decision except as the result of mutual agreement. "Arbitration," on the other hand, implies a conference and agreement, if possible; in case no agreement can be reached, then the matter at issue is to be referred for settlement to one or more persons whose decision is morally or legally binding upon both parties. In conciliation there can be a mutual agreement only; in arbitration there may be a formal and binding judgment.

Recognizing this distinction between arbitration and conciliation, the bodies formed for applying this method to labor differences assume two forms: —

First. Boards or committees of conciliation which employ conciliation only.

them. When a labor war is imminent or in progress, there is usually no place for discussion, and the decision of boards organized at such times is accepted by one party or both under duress, and is apt to be, like the board itself, temporary.

Many of the failures of arbitration and conciliation, and much of the discredit with which it is regarded, have grown out of the incompetency and shortcomings of these temporary or emergency boards. They ignore entirely what is regarded by its advocates as the most essential feature of the system,— prevention, not cure. It cannot be too often pointed out that the demand in connection with labor differences is not for a method that shall settle strikes, but for one that shall prevent labor differences, either by removing their causes or by promptly settling them before they grow to disputes. It is the claim of the advocates of arbitration that permanent boards of arbitration and conciliation, with their systematic procedure, their stated meetings, and their friendly discussions, answer this demand, and that the temporary boards, however valuable they may be in a given case, do not. These permanent voluntary boards, recognizing the perfect equality of employer and employed, and the right of each to an equal voice in the settlement of all questions, meeting at stated times, when no demand has been formulated, no positions assumed, no bitterness engendered, afford opportunities for the rapid growth of that mutual confidence which must exist if any method of harmonizing differences be effective. The great hindrance to the settlement of these questions is the unnecessary antagonistic positions of employer and employed. If these can be got to shake hands in a friendly manner, to learn to have confidence in each other, to sit down at a table as equals and talk their differences over as they arise, and before they grow into disputes, the first step for a better understanding and for a settlement of these differences is taken.

Without considering here the general question of arbitration and conciliation as against other methods of settling labor disputes, but the only, the best forms of these boards, it seem clear that the permanent boards of arbitration and conciliation are to be preferred to any temporary boards, and to boards of conciliation alone.

In their origin and methods arbitration and conciliation are either —

First. *Legal;* that is, established and operated under statute

As has been pointed out, labor differences arise concerning both past and future contracts, and also grow out of "matters of sentiment." From their very nature it is evident that it is only a very limited range of difficulties, chiefly those involving the terms and construction of contracts under which work has already been done, that legal or compulsory arbitration and conciliation, relying as it does upon the State to give effect to its decisions, can deal with any degree of efficiency. It is natural and proper that the parties to such differences, involving as they do work done and money earned,— that is, actual property,— should be compelled, if necessary, to submit their differences to a competent tribunal, and when that tribunal has honestly and carefully reached a decision, that the State by all its agencies should give it effect. In dealing with such questions these boards or committees are but courts of law unfettered by their forms or ceremonies.

But it is not concerning past contracts or work done that differences and disputes most frequently arise, but as regards the future, and here legal arbitration and conciliation is confessedly powerless. Every law providing for legal arbitration formally recognizes its limitations, and provides that the boards or *conseils* organized under them shall not deal with future rates of wages unless by mutual consent. Even then the awards cannot be enforced unless this consent is renewed after the finding. There is no power in the State to compel the performance of work under the terms of an award without recourse to practical confiscation and absolute slavery. Law cannot force men to work at rates nor upon terms to which they will not agree, nor can it compel an employer to operate his works and furnish employment. In a word, there is no power outside the parties themselves that can give effect to a decision as to a future contract or that can harmonize quarrels over matters of sentiment. It is with them that power is lodged, and to them appeal must ultimately lie. Within the realm of labor to a degree unknown elsewhere government exists only by the consent of the governed.

It is in the complete recognition of this fact at all stages of its proceedings, the submission, discussion, award, and enforcement that is the strength and justification of the system of voluntary arbitration and conciliation. It is because it furnishes a method, and the only one, for securing that consent without which no method of harmoniz-

But it is by no means clear that the future is not a proper subject of agreement or award. There are many questions relating to methods of work and administration that most certainly are. Endless confusion and innumerable conflicts would result were not these details subjects of agreement beforehand. Further, the fixing of future rates of wages is not only not theoretically unsound, but it is in accordance with the most obvious business practice and prudence. It is absolutely impossible in the present organization of industry that work should go on one moment without an agreement as to what wages shall be. This is too obvious to need discussion, and whether that agreement is for a year or for a day, it is fixing future rates of wages. There may be a question as to the proper duration of the agreement,— that is, how long the rates shall obtain,— but there can be no question as to the necessity of some agreement. Further, such fixing of future wages is exactly analogous to the very common and commendable practice of buying and selling goods for future delivery. Its advantages, in view of modern commercial methods, are beyond question. A rate of wages established for a fixed period justifies an employer in entering upon contracts for the purchase of materials and the delivery of goods with a certainty that cannot exist when these rates may be advanced tomorrow. As has been stated, the length of time an agreed rate of wages shall be in force is a subject for agreement the same as the rate itself, but even here the difficulties and injuries arising from frequent adjustments may be largely overcome by the adoption of sliding scales; indeed, these sliding scales remove many of the objections to fixing future rates of wages. Once agreed upon, under their operation, wages conform themselves to selling price, to the course of events, without confusion, without friction. It may also be said in passing that they are a practical recognition of the true theory of wages.

Another objection to arbitration is that the awards and decisions are usually compromises. By this is meant that neither party to the submission gets what it asks, or there is what is termed "splitting the difference." Even if this were true, it would not be surprising. It requires but little experience with labor differences to learn that it is by no means uncommon for both sides to demand more than they expect to get for the very purpose of having something to concede. This "higgling of the market" is as old as buying and selling. "*In*

unions and employers' associations, both to provide for the election of members of the board and to furnish that power that shall compel the acceptance of the awards.

It is not necessary, though it will usually be found advisable, to have the members of the board representing labor elected by labor in some organized form. There is, then, a tangible body responsible for the selection. To it appeal can be had, and by it discipline can be administered. An unorganized crowd is usually neither as deliberate, as wise, nor as conservative in its actions as one that has put itself under the restraint of laws, precedents, and officers.

But it is conceded that at present there seems to be no other authority possessed of the power, which at times is necessary to enforce obedience to awards, than that residing in unions. As has been pointed out, in all settlements of labor differences, by whatever method, the measure of success is the consent of the parties. Experience has shown that that consent is capricious, and the honor and pledged word of the parties at times of little value. This is as true in séttlements reached without arbitration as of those the results of this method. The necessity of a power strong enough to compel the acceptance of settlements, and so constituted that it can enforce its commands, is evident. The State, as the embodiment of law and power, has been suggested, but in these matters it is powerless. It is evident that as the measure of power is the consent of the governed, the power to enforce the awards must come from the parties themselves,— that is, unions. It will be found that the success of arbitration has been secured where there have been strong unions to compel the acceptance of the awards.

It is not my purpose to discuss the advisability of unionism. From what has already been said, it will be inferred that to the principle I give my hearty assent. I believe with the Duke of Argyle, "that combinations of workingmen for the protection of their labor are recommended alike by reason and experience." What I desire to ask those who object to arbitration on this account is, if their objection will do away with unionism, or if it will remove the necessity of recognizing and treating with unions in the near future. Unionism is here, and it will not depart. It is growing yearly in power, in wisdom, and in organization. It cannot be crushed out; it will not permit itself always to be ignored or despised. Is it wisest

been devoted to it, especially in Germany, though comparatively little has as yet been done in this line in the United States.

Viewed from the standpoint of their uses in the nutrition of man, the constituents of ordinary food-materials may be divided into (1.) *Edible substance*, e. g., the flesh of meats and fish, the shell-contents of oysters, or wheat-flour; (2.) *Refuse*, e. g., bones of meat and fish, bran of wheat. The edible substance consists of water and nutritive ingredients or nutrients. In studying the uses of food in nutrition, the nutrients only demand special consideration. Speaking as chemists and physiologists, we may say then that our food supplies, besides water, four principal classes of nutritive ingredients or nutrients, viz., protein, carbohydrates, fats and mineral matters; and that these nutrients are transformed into the tissues and fluids of the body, and are consumed to produce heat and muscular and intellectual energy.

In studying foods we may consider their chemical composition, their digestibility, their pecuniary cost as compared with their composition, the physiological economy of their use, including the functions of the ingredients, their potential energy, the quantities appropriate for the nutrition of different people, and the adjustment of dietaries to the wants of the users; and, finally, the injury to health and purse which comes from the wrong use of food, and the ways in which our dietary habits may be improved.

The term protein is applied to a variety of compounds, all of which contain nitrogen. The most important are, (1), the albuminoids, or proteids; such as the albumen of eggs, myosin of muscle (lean of meat); casein of milk and gluten of wheat; (2), gelatinoids, e. g., ossein of bone and the collagen of tendons, which, when boiled, yield gelatin. The principal carbohydrates are starch, sugar, and cellulose (woody fiber). We have examples of fats in the fat of meats, butter, olive oil, oil of corn, and wheat; among the mineral matters, the phosphates and chlorides of calcium, potassium, etc. The quantities of water, nutrients, etc., contained in different food-materials were illustrated in detail by colored diagrams, and are here shown in Tables I., II., and III.

TABLE II.

Composition of Animal Foods. Specimens as Purchased in the Markets (including both Edible Portion and Refuse).

[Italics indicate European analyses, the rest are American.]

Kinds of Food Materials.	Refuse: bones, skins, shells, etc.	Edible Portion.					
				Nutrients.			
		Water.	Nutrients.	Protein (albuminoids).	Fats.	Carbohydrates, etc.	Mineral matters.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Meats — Fresh.							
Beef, side, well fattened, .	19.7	44.0	36.3	13.8	21.7	..	0.8
Beef, round, rather lean, .	10.0	60.0	30.0	20.7	8.1	..	1 2
Beef, sirloin, rather fat, . .	25.0	45.0	30.0	15.0	14.3	..	0.7
Beef, neck, ...	19.9	49.6	30.5	15.4	14.3	..	0.8
Beef, tongue, ...	15.3	54.0	30.7	14.5	15.4	..	0.8
Beef, heart, ...	6.0	53.4	40.6	14.8	24.8	..	1.0
Mutton, side, well fattened,	20.0	42.9	37.1	13.2	23.2	..	0 7
Mutton, leg, ...	18.4	50.4	31.2	15.0	15.5	..	0.7
Mutton, shoulder, ...	16 8	48.7	34.5	15.0	18.7	..	0.8
Mutton, loin (chops), . . .	16.3	41.3	42.4	12.5	29.3	..	0.6
Meats — Prepared.							
Dried beef, ...	6.5	55.5	38.0	27.4	4.2	..	0.4
Corned beef, rather lean, .	6.2	54.5	39.3	12.5	24.9	..	1.9
Smoked ham, ...	12.5	36.3	51.2	14.6	34.2	..	2.4
Pork, bacon, salt, ...	5.0	9.5	85.5	2.8	76.5	..	6.2
Fowl.							
Chicken, rather lean, . . .	41.6	42.2	16.2	14.2	1.2	..	0.8
Turkey, medium fatness, .	35.4	42.8	21.8	15.4	5.6	..	0.8
Dairy Products, Eggs, etc.							
Cow's milk, ...	..	87.4	12.6	3.4	3.7	4.8	0.7
Cow's milk, skimmed, ...	..	90.7	9.3	3.1	0.7	4.8	0.7
Cow's milk, buttermilk, . .	..	90.3	9.7	4.1	0.9	4.0	0.7
Cow's milk, whey, ...	..	93.2	6.8	0.9	0.2	5.0	0.7
Cheese, whole milk, ...	..	31.2	68.8	27.1	35.5	2.3	3.9
Cheese, skimmed milk, . .	..	41.3	58.7	38.4	6.8	8.9	4.6
Butter, ...	..	9.0	91.0	1.0	87.5	0.5	2.0
Hen's eggs, ...	13.7	63.1	23.2	11.6	10.2	0.6	0.8
Fish, etc.							
Flounder, whole, ...	66.8	27.2	6.0	5.2	0.3	..	0.5
Haddock, dressed, ...	51.0	40.0	9.0	8.2	0.2	..	0 6
Bluefish, dressed, ...	48.6	40.3	11.1	9.8	0.6	..	0 7
Cod, dressed, ...	30.0	58.4	11.6	10.6	0.2	..	0.8
Whitefish, whole, ...	53.5	32.5	14.0	10.3	3.0	..	0.7
Shad, whole, ...	50.1	35.2	14.7	9.2	4.8	..	0.7
Mackerel, average whole, .	44.6	40.4	15.0	10.0	4.3	..	0.7
Salmon, whole, ...	35.3	40.6	24.1	14.3	8.8	..	1.0
							Salt.
Salt cod, ...	24.9	40.3	19.4	16.0	0.4	..	15.4 3.0
Smoked herring, ...	44.4	19.2	29.9	20.2	8.8	..	6.5 0.9
Salt mackerel, ...	33.3	28.1	31.5	14.7	15.1	..	7.1 1.7
Oysters, in shell, ...	82.3	15.4	2.3	1.1	0.2	0.6	0.4
Oysters, solid, ...	..	87.2	12.8	6.3	1.6	4.0	0.9
Scallops, edible portion, . .	..	80.3	19.7	14.7	0.2	3.4	1.4

TABLE III.

Constituents of Vegetable Foods and Beverages.

[The analyses of foods in Roman letters are American, those of foods and beverages in italics are European.]

KINDS OF FOOD AND BEVERAGES.	Water.	NUTRIENTS. Protean (albuminoids).	Fats.	Carbohydrates, etc.	Woody fiber.	Mineral matters.
FOODS.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Wheat flour, average,*	11.6	11.1	1.1	75.4	0.2	0.6
Wheat flour, maximum,* . . .	13.5	13.5	2.0	78.5	1.2	1.5
Wheat flour, minimum,* . . .	8.3	8.6	0.6	68.3	0.1	0.3
Graham flour (wheat), ...	13.0	11.7	1.7	69.9	1.9	1.8
Cracked wheat, ...	10.4	11.9	1.7	74.6		1.4
Rye flour, ...	13.1	6.7	0.8	78.3	0.4	0.7
Pearled barley, ...	11.8	8.4	0.7	77.8	0.3	1.0
Buckwheat flour, ...	13.5	6.5	1.3	77.3	0.3	1.1
Buckwheat "farina,"	11.2	3.3	0.3	84.7	0.1	0.4
Buckwheat "groats,"	10.6	4.8	0.6	83.1	0.3	0.6
Oatmeal, ...	7.7	15.1	7.1	67.2	0.9	2.0
Maize meal, ...	14.5	9.1	3.8	69.2	1.8	1.6
Hominy, ...	13.5	8.3	0.4	77.1	0.3	0.4
Rice, ...	12.4	7.4	0.4	79.2	0.2	0.4
Beans, ...	13.7	23.2	2.1	53.7	3.7	3.6
Pease, ...	15.0	22.9	1.8	52.4	5.4	2.5
Potatoes, ...	75.5	2.0	0.2	20.5	0.8	1.0
Sweet potatoes, ...	75.8	1.5	0.4	20.0	1.1	1.2
Pole beans, ...	83.5	2.8	0.3	10.0	2.6	0.8
Green pease, ...	81.8	3.4	0.4	12.1	1.6	0.7
Turnips, ...	91.2	1.0	0.2	6.0	0.9	0.7
Beets, ...	83.9	2.1	0.1	11.7	1.2	1.0
Carrots, ...	87.9	1.0	0.2	8.9	1.2	0.8
Onions, ...	89.3	1.1	0.2	8.3	0.6	0.5
Cabbage, ...	90.0	1.9	0.2	4.9	1.8	1.2
Lettuce, ...	94.3	1.4	0.3	2.2	0.7	1.1
Cauliflower, ...	90.4	2.5	0.4	5.0	0.9	0.8
Tomatoes, ...	92.4	1.3	0.3	4.6	0.8	0.6
Melons, ...	95.2	1.1	0.6	1.4	1.1	0.6
Pumpkins, ...	90.0	0.7	0.1	7.3	1.3	0.6
Squash, ...	87.8	0.7	0.2	9.1	1.1	1.1
Apples, ...	84.8	0.4	..	12.8	1.5	0.5
Pears, ...	83.0	0.4	..	12.0	4.3	0.3
Starch, ...	15.1	1.2	..	83.3	..	0.4
Tapioca, ...	13.3	0.6	86.0		..	0.1
Cane-sugar, ...	2.2	0.3	..	96.7	..	0.8
Molasses, ...	24.6	..	..	71.0	‡	2.3
Wheat bread,†	32.7	8.9	1.9	55.5		1.0
Graham bread, ...	34.2	9.5	1.4	53.3		1.6
Rye bread, ...	30.0	8.4	0.5	59.7		1.4
Soda crackers, ...	8.0	10.3	9.4	70.5		1.8
"Boston" crackers, ...	8.3	10.7	9.9	68.7		2.4
"Oyster" crackers, ...	3.9	12.3	4.8	76.5		2.5
Oatmeal crackers, ...	4.9	10.4	13.7	69.6		1.4
Pilot (bread) crackers, ...	7.9	12.4	4.4	74.2		1.1
Macaroni, ...	13.1	9.0	0.3	76.8		0.8
BEVERAGES.			Alcohol		Free acid.	
Lager beer, ...	90.3	0.5	4.0	5.0	..	0.2
Porter and ale, ...	88.5	0.7	5.2	5.3	..	0.3
Rhenish wine, white, ...	86.3	..	10.5	2.6	0.4	0.2
Rhenish wine, red, ...	86.9	..	8.9	3.4	0.5	0.3
French wine, claret, ...	88.4	..	8.1	2.7	0.6	0.2

* Of analyses of American flours. The figures for "maximum" and "minimum" denote the largest and smallest percentages, respectively, found in the analyses. The sum of the figures representing the maximum must, therefore, exceed, and those for minimum fall below, 100 per cent.

† *From flour of about average composition.*

‡ Other organic matter, 2.1.

Thus in lean beef, such as round steak as we buy it in the markets, there is about ten per cent of refuse in the form of bone, sixty per cent of water, and thirty per cent of nutrients, of which latter the protein makes up twenty-one per cent, the fats eight per cent, and the mineral matter one per cent. The quantity of refuse in our ordinary meats varies from five to twenty-five per cent, or thereabouts, the water from ten per cent in fat pork to sixty per cent in lean beef, and the total nutrients from eighty-five per cent in fat pork to thirty per cent or forty per cent in ordinary beef and mutton. The protein, which is the most valuable of the nutrients, ranges from twelve to twenty per cent in beef and mutton, and from two to twelve per cent in pork. The most marked difference among the meats is in the quantities of fat, which may be as low as eight per cent or lower in lean beef and veal, or as high as twenty-five per cent in fat beef and mutton, and may reach seventy-five per cent in fat pork. Fish, as we buy them, contain more refuse and water and less nutritive material than the meats, the quantities of nutrients varying from six per cent in fresh flounder and twelve per cent in fresh cod, to twenty per cent in salt cod and thirty-two per cent in salt mackerel. The nutrients of fish consist mostly of protein. When, however, we consider the edible portion of meats and fish after the bone and other refuse has been removed, there are, of course, proportionally larger quantities of nutrients. Ordinary cow's milk contains about twelve and a half per cent of nutrients and eighty-seven and a half per cent of water. While the nutrients in milk are thus about one-eighth of the whole, those of cheese make about two-thirds, and those of butter nine-tenths of the whole weight. Oleomargarine has about the same composition and nutritive value as butter. Oysters, like milk, contain about one-eighth nutrients and seven-eighths water. The oysters have rather more protein than the milk, while the milk has more of fats than the oysters. The vegetable foods have, in general, less water and more nutrients than the animal foods, but potatoes, turnips, and the succulent vegetable food materials generally have large quantities of water. Thus the potato has about three-quarters water and one-quarter nutritive material. But a most important difference between the vegetable and the animal foods is found in the fact that the vegetables in general contain large quantities of carbohydrates, of which the animal foods contain little or none. Wheat flour has on

flour. There is, therefore, no special economy in leaving the bran in the wheat in grinding, though the therapeutic effect of the bran is sometimes beneficial. Of the carbohydrates of vegetable foods from eighty to ninety per cent are digested. Those of coarse bread, potatoes, and beets are the least, and those of ordinary flour and meal the most, completely digested. The fats of various food materials are variable in digestibility.

The comparative costs of actual nutrients of foods are found by comparing the composition with the price. One method consists in comparing the costs of a given class of nutrients, as, for instance, protein in the different food materials. Table IV. gives the results of these computations.

TABLE IV.

Comparative Expensiveness of Actual Nutrients of Foods.—Costs of a Pound of Protein in Different Food Materials at Ordinary Prices.

(Allowance being made for the other nutrients in each case.)

FOOD MATERIALS.	Prices.	Costs of Protein. Cents.
Beef, sirloin, ...	25 cents per pound.	106
Beef, "	20 " "	86
Beef, round, ...	18 " "	70
Beef, neck, ...	8 " "	33
Beef, tenderloin, ...	60 " "	235
Mutton, leg, ...	22 " "	91
Pork, salted, fat,*	12 " "	25
Salmon, ...	30 " "	153
Shad, ...	12 " "	99
Cod, ...	8 " "	75
Canned salmon, ...	20 " "	70
Salt cod, ...	5 " "	31
Oysters, ...	50 " per quart.	336
Milk, ...	8 " "	61
Cheese, whole milk, ...	15 " per pound.	31
Cheese, skimmed milk, ...	8 " "	18
Wheat flour, ...	4 " "	15
Wheat "	3 " "	12
Wheat bread, ...	6 " "	29
Indian meal, ...	3 " "	12
Indian "	2 " "	8
Oat meal, ...	5 " "	15
Beans	10 " per quart.	14
Potatoes,*	100 " per bushel.	30
"	50 " "	15

* Contain very little protein.

TABLE V.

Quantities of Nutrients Obtained for 25 Cents in Different Food Materials when Purchased at Ordinary Prices.

	At prices per pound. Cents.	Food materials obtained. Pounds.	Nutrients in Food Materials. Protein. Pounds.	Fats. Pounds.	Carbo-hydrates. Pounds.	Potential Energy. Foot-tons.
Beef, sirloin, medium fatness,	25	1.00	.15	.14	–	6042
Beef, " " "	20	1.25	.19	.18	–	7730
Beef, round, ...	18	1.39	.29	.11	–	6971
Beef, neck, ...	8	3.13	.48	.44	–	19098
Beef, tenderloin, ...	60	.42	.09	.03	–	2737
Mutton, leg, ...	22	1.14	.17	.17	–	7171
Pork, salted, fat, ...	12	2.08	.06	1.59	–	47367
Salmon, ...	30	.83	.12	.07	–	3602
Shad, ...	12	2.08	.19	.10	–	5386
Cod, ...	8	3.13	.33	.01	–	4557
Canned salmon, ...	20	1.25	.25	.19	–	8798
Salt cod, ...	5	5.00	.80	.02	–	10924
Oysters, 50 cents per quart, .	25	1.00	.06	.02	.04	1878
Milk, 8 cents per quart, . . .	4	6.25	.21	.23	.30	13330
Cheese, whole milk, ...	15	1.67	.45	.59	.04	23620
Cheese, skimmed milk, . . .	8	3.13	1.20	.21	.28	25278
Butter, ...	30	.83	–	.73	–	21391
Wheat flour, ...	4	6.25	.69	.04	4.71	70950
Wheat "	3	8.33	.92	.09	6.28	95674
Wheat bread, ...	6	4.17	.37	.07	2.31	36682
Indian meal, ...	3	8.33	.70	.29	5.91	93911
Indian "	2	12.50	1.05	.44	8.87	141077
Oat meal, ...	5	5.00	.76	.36	3.36	63787
Beans, 10 cents per quart, . .	5	5.00	1.16	.11	2.69	52972
Potatoes, $1.00 per bushel, . .	1.7	13.24	.27	.03	2.74	39773
Potatoes, 50 cents per bushel,	0.85	26.47	.53	.05	5.48	79125
Daily dietary for laboring men at moderate work, ...	–	–	.26	.12	1.10	21221

It is worth the noting that oat meal is one of the cheapest foods that we have; that is, it furnishes more nutritive material, in proportion to the cost, than almost any other food. Corn meal is, indeed, cheaper, but the oat meal has this great advantage over corn meal and wheat flour, that it has more protein. Of course, if we are to eat large quantities of lean meat,—and many people, doubtless, eat more than is best for their health, saying nothing of their purses,—the

rial for fuel. For this purpose either protein, fats, or carbohydrates may do, to greater or less extent, but the most healthful diet is one that contains all these ingredients in proper portions.

Another matter of interest is found in the quantities of potential energy contained in our foods. When coal is burned under the steam boiler, heat is developed by the union of its carbon with oxygen. When the water changes to steam in the boiler, this heat is transformed into mechanical energy with which the engine does its work. In like manner the nutrients of our foods are consumed in the body, and yield heat and muscular energy. The amount of mechanical energy which would raise one ton to the hight of one foot is called a foot-ton.

TABLE VI.

Potential Energy in Nutrients of Common Food Materials.—Mechanical Equivalents Expressed in Foot-Tons of Energy in One Pound of Each Food Material.

EDIBLE PORTION. (Flesh freed from bone and other refuse.)		SPECIMENS. (Including edible portion and refuse.)	
Beef, lean, nearly free from fat,	679	Beef, round, rather lean,	1113
Beef, round, rather lean, . . .	1237	Beef, sirloin, rather fat,	1351
Beef, sirloin, rather fat, . . .	1797	Beef, neck, ...	1362
Beef, neck, ...	1697	Mutton, leg, ...	1428
Mutton, leg, ...	1749	Mutton, loin (chops), .	2250
Mutton, loin (chops), ...	2689	Smoked ham, ...	2626
Flounder, ...	438	Pork, very fat, salted, .	5023
Cod, ...	476	Flounder, whole, . . .	167
Mackerel, ...	1066	Cod, dressed, ...	315
Salmon, ...	1481	Mackerel, whole, . . .	563
Oysters, ...	352	Salmon, whole, . . .	975
Cow's milk, ...	472	Salt cod, ...	481
Cow's milk, skimmed, . . .	270	Salt mackerel, ...	1394
Cheese, whole milk, ...	3130		
Cheese, skimmed milk, . . .	1786		
Butter, ...	5654		
Wheat bread, ...	1958		
Wheat flour, ...	2534		
Corn meal, ...	2475		
Oatmeal, ...	2803		
Beans, ...	2326		
Rice, ...	2492		
Sugar, ...	2755		
Potatoes, ...	655		
Turnips, ...	213		

TABLE VII.

DAILY DIETARIES.

Quantities of Nutrients and of Potential Energy in Nutrients.

DIETARY OF —	Protein.	Fats.	Carbo-hydrates.	Potential Energy.
	grams.	grams.	grams.	Foot-tons.
Stan'rd for laborer at moderate work. Voit,	118	56	500	21221
Stan'rd for laborer at severe work. Voit,	145	100	450	23409
Poor sewing girl, London, England, . .	53	33	315	12614
Poor factory girl, Leipsic, Germany, . .	52	53	301	13479
Poor laborers, Lombardy, Italy, ...	82	40	362	15231
Monk, in cloister, ...	68	11	469	16006
Privy councilor, Marburg, Germany, . .	90	79	285	15785
University professor, Munich, Germany,	100	100	220	15576
Physician, Munich, Germany, ...	134	102	291	18696
Adults, with moderate exercise, England,	120	40	530	21099
Mechanic, Munich, Germany, ...	117	68	345	17553
Hard-working laborers, Bavaria, ...	132	51	583	23661
Hard-working laborers, England, ...	160	66	579	25314
Brewery laborers, Munich, severe work,	149	61	755	29690
Brewery laborers, Munich, severe work, exceptional diet, ...	223	113	909	39544
German soldiers, peace footing, ...	114	39	480	19439
German soldiers, war footing, ...	134	58	489	21493
German soldiers, war footing, extraordinary ration, ...	191	45	678	27660
French Canadians, Can., working people,	109	108	525	25036
French Canadians, Mass., factory operatives, etc., ...	119	202	551	32135
Other factory operatives and mechanics, Mass., ...	126	185	530	30638
Glass-blower, Cambridge, Mass., ...	95	132	481	24935
College students from Eastern States. { Food purchased, .	161	204	681	37163
College students from Eastern States. { Food actually eaten	148	185	681	35565
Machinist, Boston, Mass., ...	181	254	617	39141
Brickmakers, Middletown, Conn., ...	222	263	758	44906
Brickmakers, Massachusetts, ...	180	365	1150	61465

The food of poorly-paid laborers in England, France, and Germany is thus seen to be deficient in nutrients.

The dietaries of peasants in Lombardy, who live upon corn meal, were very deficient, especially in protein; they suffer terribly from a disease called pellagra. It is found that when they have, along with the corn meal, other food which supplies the lacking nutrients, the disease speedily disappears. The food of well-to-do English, French, and German mechanics and laborers was fully up to the standard,

ther study. Doubtless the results of such investigation, rightly conducted, would throw very important light upon the problem of the ratio between wages and production.

Reference was also made to the food of the poor in Boston and other places. It was insisted that the people of the poorer classes are really least economical of all in their purchase and use of food, and that the instruction of the poor, and of people in moderate circumstances, in the elements of food economy, would be one of the most excellent ways in which knowledge may be utilized and charity exerted. One of the fortunate signs of the times is found in the work done in this direction in some of the schools in Boston, and in such work as that of Mrs. Richards in the Institute of Technology. The fact that these important problems are being taken hold of, and the results of scientific research applied in the ways mentioned, is extremely gratifying.

The meeting was brought to a close by a vote of thanks to the speaker.

MEETING 348.

The Micro-Membrane Filter.

BY PROF. W. R. NICHOLS.

The Creque System of Defecating, Storing, Circulating, and Employing Water for Domestic Purposes.

BY MR. ALLEN P. CREQUE.

The 348th and annual meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, May 13th, at 8 P. M., President Walker in the chair.

After the reading of the minutes of the previous meeting, the Nominating Committee presented their report, and officers were elected for the ensuing year.

The report of the Executive Committee was read, and ordered placed upon the records.

largely through a better knowledge of storm laws that practical meteorology may be advanced. The study of the thunder storms of last summer, under the direction of Prof. Davis, of Cambridge, has given promise of valuable results from the much-extended investigations to be made the coming summer.

THE MICRO-MEMBRANE FILTER.

The President then introduced Prof. W. R. Nichols, of the Institute, who described the Micro-Membrane Filter.

Prof. NICHOLS said: The so-called micro-membrane filter, which I bring before you this evening, is the invention of one Friedrich Breyer, of Vienna. This filter does not claim to exert any chemical effect upon the water, but relies for its efficacy upon the excessive minuteness of its pores through which the water must pass.

The material employed is asbestos. The value of this material as a filtering medium is well known to chemists, and it is frequently made use of in the laboratory; but the material which we there use is not as fine or as elaborately prepared as that used in these filters. The asbestos is first carefully selected and ground in a mill. We all know how a sheet of mica may be split into thinner and thinner layers; in the same way the threads of asbestos may be split longitudinally into thinner and more delicate threads. Practically, this is accomplished by grinding the wet asbestos with about its own weight of crystallized carbonate of lime, the carbonate of lime being subsequently dissolved out with hydrochloric acid. The resulting asbestos pulp is then allowed to deposit upon cloth stretched in an apparatus so arranged that the pressure may be diminished beneath it, and the asbestos film, or membrane, thus produced is a very different thing from ordinary asbestos paper. While water will pass through the pores, the finest solid particles are arrested, the film being made very thin to facilitate the passage of the water.

[Drawings of the fibers of cotton, sponge, a thread of silk, a spider-web thread, and fibers of asbestos, magnified a thousand times, were exhibited on the board, showing very clearly the extreme fineness of the asbestos fiber.]

It is calculated that with only three superimposed individual layers of this asbestos film there would be in every square millimeter two and a quarter million pores, or openings, for the passage of water.

Personally, I am quite content with this proof of the efficacy of the filter, and I think in its larger forms, with attached reservoir, it may serve a good purpose. Of course, in this country, these small filters which take an hour to filter a quart of water would be quite useless. No one will wait fifteen minutes for a glass of water to filter through; he would rather take his chances with a few more microbes.

I do not lay so very much stress upon this matter of "germs," in the present connection. First, because there is no proof that the number of microbes bears any direct relation to the wholesomeness of the water; second, because a water furnished or used for domestic supply ought not to contain *dangerous* organisms requiring removal; third, because, even if it were possible to obtain a germ-free water by carefully sterilizing the whole apparatus and receiving the filtered water in sterilized vessels, such water would not be obtained in the ordinary use of the apparatus. I hope, however, for my own satisfaction to make some experiments on the material by itself, arranged for laboratory use, independently of the apparatus. In some experiments already made with the apparatus as arranged, I have not found it possible to sterilize by filtration an infusion of hay, although the filtered liquid was perfectly clear and bright as it came through the filter, and was received into carefully sterilized flasks.

THE CREQUE SYSTEM OF DEFECATING, STORING, CIRCULATING, AND EMPLOYING WATER FOR DOMESTIC PURPOSES.

At the conclusion of Prof. Nichols' paper, the President introduced Mr. Allen P. Creque, of New York, who read a paper on the "Creque System of Defecating, Storing, Circulating, and Employing Water for Domestic Purposes."

After a few preliminary remarks, the speaker exhibited a large sectional diagram of the common "kitchen-range boiler," with which he proceeded to explain and illustrate the serious defects in their construction, form, connecting devices, and their imperfect mode of circulating the heated water; also, a large number of other diagrams illustrating the construction, form, and connecting appliances of the Creque system of hot water circulation. The three accompanying illustrations, selected from the exhibit, and explanations, will assist in making the essential features understood. (See Fig. 1.)

When there is an accumulation of hot water in the circulator A, if a faucet on the hot water delivery pipe M should be opened, the hot water in the hot water depository will instantly commence to ascend through the coupling C and hot water delivery pipe M directly to the discharging faucet.

If a faucet be opened upon the hot water delivery pipe O, which is intended to furnish heated water for use upon floors level with, or below, the circulator, heated water from the hot water depository will immediately descend through the hot water delivery tube N, and, passing through the compound coupling B, will be conveyed by the hot water delivery pipe O directly to the discharging faucet.

Should a faucet be opened, simultaneously, upon each of the hot water delivery pipes M and O, heated water from the hot water depository will instantly proceed to both of the discharging faucets, impelled by an equal division of the pressure contained in the cold water supply.

Should the cold water supply be withdrawn in the cold water supply tube E, the automatic check-valve F will instantaneously rest upon its seat, formed by the discharge end of the cold water supply pipe E, and effectually prevent the return flow of the cold water from the circulator A into the cold water supply tube E.

When the automatic check-valve F is closed, any undue pressure created by the expansion of water in the heater K will escape through the relief-valve tube G and the automatic relief-valve contained in the check-valve F into the cold water supply tube E.

Sediment is discharged from the circulator A through the compound coupling B and multi-cock into the sediment pipe P.

Incrustations, compact sand deposits, etc., which cannot be discharged through sediment pipe P, may be detached, taken out, and the circulator thoroughly cleaned by removing the coupling C and compound coupling B, which will provide two large orifices, or hand-holes, in the circulator.

Figure 2 represents a hot-water circulator with "return circulation" connections. Cold water from the cold water supply tank T flows downward through the cold water supply pipe R, and, passing through the multi-coupling C, is conducted by the connecting cold water supply tube S to near the bottom of the circulator A, where it is discharged laterally. Cold water within the circulator A enters the inlet

FIG. 3.

for "apartment houses" where the hot water is required only upon the floor occupied by the circulator.

The hot water circulator, illustrated upon the second floor (fig. 3), has the same pipe connections as the circulator upon the first floor of same figure, except that the cold water supply is furnished from a tank T upon the fourth floor. The cold water is conveyed in the cold water supply pipe R to the coupling in the top end of the circulator A through which it flows into the cold water supply tube S, and is discharged laterally into the circulator A a short distance above the sediment that may be resting upon the bottom end of the circulator.

The horizontal hot water circulator, illustrated upon the third floor (fig. 3), receives its cold water supply from tank T, located upon the fourth floor. The cold water supply is conveyed by the cold water supply pipe R to the multi-coupling C, secured in the end of the circulator A through which it flows into the cold water supply tube S, and is discharged laterally into the circulator above the sediment level. The cold water within the circulator enters the inlet of the cold water circulation tube H above the discharging orifice of the cold water sup-

tube whenever the pressure within the circulator and its connections exceeds the maximum hydrostatic pressure of the cold water supply.

The lateral discharge of the cold water supply, within the circulator, some distance above its bottom end, promotes the speedy deposit, by gravity, upon the circulator bottom of the coarse vegetable, mineral, and organic substances contained in the feculent cold water supply. This produces a necessary and very important partial purification in the contents of the cold water repository. Entering some distance above the sediment level, it also prevents the disturbance or agitation of any sedimentary matter which may be resting upon the bottom end of the circulator. Only the purer cold water is permitted to enter the circulator and flow into the heater, as the inlet of the cold water circulation tube is elevated a considerable distance above the sediment level, and also above the discharging orifice of the automatic check-valve, seated upon the outlet end of the cold water supply-tube. Hence, it is impossible for either the sedimentary matter resting upon the circulator bottom end or the feculent cold water supply to be absorbed into the circulation and diffused throughout the entire volume of water within the circulator, thus polluting the hot water discharged for use, and inducing the formation of incrustations in all parts of the circulator and its pipe connections. By preventing the circulation pipes and heater from being coated and clogged with filth, it materially increases the production of heated water, and also its rapid circulation. It also saves much trouble and expense, otherwise necessary, in frequently taking apart the whole apparatus for cleaning.

The temperature of the water being increased in the heater, the heated water will immediately proceed directly to any hot water faucet, discharging either above or below the level of the circulator without passing into the circulator, or being chilled by contact with, or dispersion into, the cold water volume. An increase in its temperature compels the water to find an exit from the heater, and to advance directly into the extreme upper section of the circulator, where many of the finer deleterious substances, held in suspension and solution, naturally separate and descend by gravity to the circulator bottom, effecting a second and more thorough purification of the heated water. The heated water is generally retained a considerable time in the circulator, and also circulated many times through the

the high, undesirable, and injurious temperature of the kitchen, and utilizes the continual radiation of heat from the "circulator" to maintain a mild, agreeable, healthful atmospheric temperature in the bath-room.

A vote of thanks to the speaker brought the meeting to a close.

MEETING 349.

The Latest Development of the Bessemer Process, or the Blowing of Small Charges.

BY PROF. T. M. DROWN.

The 349th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, May 27th, at 8 P. M., President Walker in the chair.

After the reading of the minutes of the previous meeting, the President introduced Prof. T. M. Drown, who read a paper on "The Latest Development of the Bessemer Process, or the Blowing of Small Charges."

Prof. DROWN said: The question of the advantages to be gained in the blowing of small charges is still in its controversial stage, and the best I can hope to do in its treatment is to give the results of experiment and regular practice from both a chemical and physical standpoint, and to discuss the claims made for the method by those who believe it to be a valuable modification of the regular process, and also to give the criticisms of those who assert that there is really nothing new or valuable in the modification, except so far as special, geographical, and financial conditions may make its introduction desirable.

The discussion naturally assumes three divisions: —

First. Is the product of the Little Bessemer process better — that is, more uniform, more reliable, softer, more ductile, more easily

welded, more easily made — than the product of the regular Bessemer process, when using the same pig iron?

Second. Can the Little Bessemer process use inferior, cheaper, — that is, less pure pig iron,— than the regular process, and yet give as good a product?

Third. Can the Little Bessemer process exist side by side with the regular process?

At Avesta, in Sweden, where the Little Bessemer was first tried about eight or nine years ago, the converter is of the regular English revolving pattern, while in the Clapp-Griffith modification, in use in this country, the old Swedish stationary converter is used, with certain modifications; but both procedures have in common the small charges.

The description of the process at Avesta we owe to Prof. Josef von Ehrenwerth, of Leoben, in Austria, who visited these works in 1884. In Avesta there are two converters, movable on their axes by hand power. The bottom is secured by a screw. The hight of the converter is 51 to 54 inches, and the diameter 39 inches. The bottom is made of one piece, and contains about 90 tuyeres .12 to .13 of an inch in diameter, distributed in a circle of only eight inches; they are inclined at an angle of 45° to 50°.

The molds are filled directly from the converters, no ladle being used, and steel and cinder are poured out together. The blast is supplied by the same engines that supply the blast furnace, and are capable of blowing 15 lbs. to the square inch. The charge is taken directly from the blast furnace, and weighs from 375 to 1700 lbs.,—on an average, say about 1000 lbs., and 45 to 50 charges are blown in each converter in 24 hours, which includes the necessary changes of converters and bottoms. The blows seen by Ehrenwerth lasted 13.5 and 9 minutes respectively. The course of the blow is essentially the same as in the regular Bessemer process, except that it is completed with low pressure of blast.

Notwithstanding that cold charges are often blown, and notwithstanding the small amount of metal in the vessel, the steel is thoroughly and normally hot at the finish. At the end of the blow, 8 per cent of ferro-manganese is added, in small pieces, cold (the vessel being on its side), the mixture is rabbled with a stick of wood, allowed to stand quietly for some minutes, and then slowly poured into molds without any attempt to hold back the cinder.

As the results of a year's working (1879) there was 87.4 per cent of ingots produced to 12.6 per cent loss on the pig iron used, and since then a better record has been shown. There is no loss by skulls in ladles, and as the slag is poured with the steel into the molds, there is less loss at the top of the ingot.

The product is exclusively ingot iron, with carbon from .2 to .25 per cent. The amount of phosphorus in the Avesta pig iron, namely, .047 per cent, renders it unfit, it is thought in Sweden, for steel, and consequently only soft ingot iron is made. This sounds strangely to those who are compelled to use pig irons much higher in phosphorus. But, owing to the abundance of ores in Sweden, which contain only .015 per cent of phosphorus, or even less, this amount, .047, which would be considered in most countries extremely low, is thought dangerously high in Sweden.

Ehrenwerth, in describing the product, says: It is characterized by its excellent quality, by its uniformity in strength; but, above all, by its fibrous, or, better said, by its silky texture, in which respects it surpasses the best varieties of refined or puddled iron.

Analyses of the pig iron, and of the final product, are as follows: —

	Pig Iron.		Bessemer Iron.	
Carbon,	?	?	0.20	0.25
Silicon,	1.40	1.46	0.05	0.11
Manganese,	0.63	0.47	0.31	0.31
Phosphorus,	0.043	0.047	0.051	0.05
Sulphur,	0.01	0.00	0.00	0.00
Slag,	-	-	0.05 to	0.5

Ehrenwerth considers this product to be distinguished chemically by the presence of slag and the absence of sulphur. He does not comment on the amount of silicon, which, indeed, in these analyses is not particularly remarkable. It is higher than we would expect, and

in getting the pig metal from the blast furnace to the converter, the process proceeded nominally, with sufficiently high temperature, and the final product poured well. The time was 13 to 20 minutes, the pressure of blast 12 to 18 lbs. The cinder separated well from the metal in the ingot molds, and the ingot had a convex surface. The metal worked well, and was softer than the ordinary Bessemer metal made at the same works. Broken ingots showed very many small blow holes, but no particles of cinder were visible, although in taking the ingot out of the mold it was found completely covered with a crust of cinder about one-tenth of an inch thick. The ingots were converted into ship plates and boiler plates which were softer than similar metal with the same contents of carbon. The tensile strength in plates of three-tenths to five-tenths of an inch thick, unannealed, was 60,000 to 68,000 lbs., with an elongation of 22 to 26 per cent in a length of eight inches. When annealed it had a tensile strength of 54,600 to 57,000, and an elongation of 24.75 per cent to 27.75 per cent.

The softest metal made in this experimental converter contained .14 per cent of silicon, and .12 carbon, and the hardest .075 silicon and .71 carbon. Here again I suspect that there is an error in the silicon determinations owing to intermingled slag.

In a second series of experiments, with a new converter, near the blast furnace, it was found that it was not always feasible to take the iron direct from the blast furnace. Irregularities in the working of the furnace, poor fuel, etc., often gave rise to cold charges, and the process, as thus conducted, was unsatisfactory. Subsequently the small charge, 1400 to 1600 lbs., was taken from the ladle which supplied the large converters, and thus a large and a small charge were blown at the same time from identically the same iron. This gave an opportunity for a direct comparison of product, and it was found that the metal made in the small converter was always better than that blown in the large converter. Large quantities of the product of the small vessel were made into wire, sheets, and boiler plate. It was decidedly tougher than puddled iron, while its weldability was perfectly satisfactory.

Of 60 consecutive charges blown for soft metal in this converter, the average amount of silicon was 0.0281 per cent; of carbon, 0.1166 per cent.

Of these charges	18	per cent had under	0.02	per cent silicon.
	48.6	" " between	0.02 — 0.03	" "
	18	" " "	0.03 — 0.04	" "
	11.6	" " "	0.04 — 0.05	" "
	3.8	" " "	0.05 — 0.055	" "

The lowest silicon was 0.014 per cent, and the carbon varied from 0.08 to 0.16 per cent. Of the corresponding charges in the large converter, when the same degree of softness was aimed at, the average was 0.055 per cent of silicon, and 0.126 per cent of carbon. The extremes of silicon in the metal made in the large converters are, unfortunately, not given by Hupfeld.

From these comparative experiments, Hupfeld has shown that, when in the Little Bessemer process the carbon is brought down to the same point as in the regular process, the silicon is then more completely eliminated than it is in the regular process.

Let us now examine the variety of the Little Bessemer process which has been introduced into this country from Wales, under the name of the patentees, Clapp and Griffith. Their converter is of the original Swedish pattern, its peculiar features being, as stated by Mr. R. W. Hunt in a paper read before the American Institute of Mining Engineers, in February, 1885, a slag tap-hole, at such a hight in relation to the metal under treatment, that when the cinder is formed and it boils up as the blow progresses, it can run off, and thus be removed from contact with the iron, and will also be out of the way when the decarbonized metal is tapped into the casting ladle and the manganiferous alloy added. The tuyeres are situated around the body of the vessel, and enter the interior at some distance above the bottom. At first the converters were made with devices, more or less complicated, for shutting off the blast; but these are not now used. In practice, it is found that the slackening of the blast to a very low pressure suffices to keep the metal from clogging the tuyeres. At the completion of the operation the metal is tapped into a ladle, and is there mixed with the ferro-manganese, and then cast into ingots in the usual way.

The Clapp-Griffith procedure has, in common with that at Avesta and Prevali, the small charges, but it differs from them in having large side tuyeres, with low pressure of blast (five to eight lbs.), and in the practice of tapping off the cinder at the appearance of the flame.

No importance, I think, need be attached to the fact of the stationary converter, and to the fact that a ladle is used in casting.

The characteristic appearance in a Clapp-Griffith blow is the abundance of red smoke, which often forms dense clouds. The more the bottom is worn, which brings the tuyeres nearer to the surface of the metal, the more abundant is the smoke. It is clearly oxide of iron, and indicates an excess of air near the surface of the metal,—that is, more oxide of iron than the carbon and silicon can appropriate. This smoke has not been mentioned in the descriptions of the Avesta and Prevali blows, and there is less reason why we should expect it there, for in these cases the air passes through the mass of metal, and the oxide of iron formed at the bottom has an opportunity either to be reduced before it reaches the surface, or to combine with the silica of the lining. It is, however, conceivable that heavy overblowing, particularly when the carbon and silicon are nearly all oxidized, would give iron-oxide fumes even in bottom-blowing.

The product of the Clapp-Griffith converter is likewise characterized by low silicon, and it is claimed that this low silicon is a necessary result of this system of blowing. Many of the reported analyses give simply "trace" of silicon, a term variously used by chemists to express a very small amount. (It should be banished from the chemist's vocabulary, for when he cannot express an amount in figures he had better say "none.") But there are not lacking many accurate determinations, and these are all very low. Mr. McCreath gives some results as follows: 0.008, 0.004, 0.004, 0.009 per cent. These figures are probably not exceptional, but it would not be correct to say that all the product is as low in silicon. It may, perhaps, be safe to say that the Clapp-Griffith metal does not often exceed 0.02 per cent of silicon. Whether it is more uniformly low than that made at Prevali I cannot say, but I am inclined to think it probable.

Unfortunately, there are not on record many analyses of Clapp-Griffith metal low in phosphorus, and we cannot, therefore, compare its physical properties with those of the metal made in the small converters at Avesta and Prevali.

We have already seen that the blowing of small charges was not originally proposed with the idea that the product would prove to be of exceptional excellence; but if we admit that the product is exceptionally soft and ductile (as we certainly must if we accept the state-

ments of competent judges), what explanation can we give of the fact?

It is interesting in this connection to note the criticisms of Tunner, the distinguished Austrian iron metallurgist, on the Avesta process, and on the experiments at Prevali. He says he cannot see any reason why the Little Bessemer should give a superior product, and he asserts that the best way to make a soft ingot iron is by the Martin or the basic process. The only claim he will allow for the new variation is the low cost of installation, and local conditions must decide, in each instance, whether this low cost is true economy. He suggests that the reason of the soft character of the Avesta metal may be the result of the necessity of making a metal of perfect welding properties to remedy the imperfections of metal, and he intimates that there must be some disadvantages connected with the procedure, or it would have already found more general introduction. He does not discuss the question of low silicon, and while he claims that steel, in every respect as good in quality, and as soft and ductile, is made regularly at Neuberg, he does not inquire whether there may not be conditions in the small converter which necessarily tend to produce soft metal.

Ehrenwerth, in reply to Tunner, repudiates the idea that the Avesta works were driven to making a soft product to cover up the defects of the metal, but his defence of the fibrous character of the product is certainly weak. While he admits that homogeneous metal, when properly treated, is superior to weld metal, yet he argues that fibrous, that is, weld metal, is still preferred by many iron workers for various purposes, since its fibrous character is a guarantee of its softness and weldability. Avesta metal supplies this demand with a metal really superior to the ordinary weld iron.

There seems to be more misconception about fibrous iron than any other subject in iron metallurgy. Soft iron, whether homogeneous or welded, will give evidence of fiber if slowly torn apart by bending or stretching. What is a fiber? Simply an elongated mass or crystal of iron. When a fiber is broken short off by a sudden blow, what is the appearance of the fracture? Distinctly crystalline, with no trace of a fiber. To judge of the character of a sample of iron by means of the fracture, one must know how the fracture was produced. Now, it is true that in soft weld iron the fibrous character

of the metal is more easily developed and recognized, probably because the particles of iron are more or less separated by cinder. Shall we claim, therefore, that we improve the quality of iron by mixing it with a solid inert substance to break up its continuity?

When the question is put in this way, the absurdity of an admission seems evident, and yet there is one advantage of broken continuity, namely, that it opposes the transmission of fracture. Homogeneous iron or steel may be compared to glass, where an incipient crack will easily be transmitted through the mass. Weld metal may be compared to wire cable, in which a defect in one wire is confined to that wire, and is not transmitted to the others. Still, it seems clearly a retrograde step to mix cinder with ingot metal to get a fibrous product. The manipulation of ingot or homogeneous metal is, today, thoroughly understood, and no one hesitates to use it for bridge rods, steam boilers, or other similar purposes. If the metal is sufficiently soft and ductile, we need no slag to make it safe.

Ehrenwerth in reply to Tunner has no explanation to give of the superior quality of the Avesta metal other than the fact that low silicon pig iron is used, and that the wind is more thoroughly mixed with the iron, owing to the large number of very small tuyeres. It has long been a matter of comment that in Sweden pig iron is successfully blown that contains much less silicon than that used in other countries. Mr. Firmstone, of the Glendon Iron Works, Easton, Pa., has, I think, given a satisfactory explanation of this phenomenon,—namely, the much larger proportion of carbon dioxide formed in the gases of the Swedish converter. It is evident that when the carbon is merely burned to carbon monoxide there is much less heat generated than when it is burned to carbon dioxide. In other words, in Swedish practice there is more air blown in proportion to the amount of pig iron used than is usual elsewhere, and consequently some of the carbon reaches its highest point of oxidation. Side blowing, now generally practiced as a remedy for cold charges, is effective for the same reason.

If we look to the chemical composition for a solution of the question, we must accept Hupfeld's view, that it is due to the more complete elimination of silicon in the Little Bessemer. He says the only respect in which the soft Bessemer metal, made in Austria, is inferior to basic or Martin steel is in the somewhat higher percentage of silicon, namely, 0.035 to 0.06 per cent. Now, as we have already seen,

is no tendency, as far as noted, for the formation of skulls. There is, to be sure, relatively more heat lost by radiation in small charges than in large ones, and probably there is less opportunity for abnormally high heats being developed in the small vessel. As far as this goes, then, the tendency is to eliminate the silicon. But may there not be a counteracting tendency in the facility with which a proportionately larger amount of air may be forced into the small vessels? Still, if we admit, in the absence of any determinations of temperature, or of the composition of the gases, that the temperature in the small vessel is probably rather low than high, we have a favorable condition for the elimination of silicon. But this, clearly, is not a sufficient explanation to cover all cases.

In the small vessel, owing to the facility with which the charge can be treated with an excess of air, it seems probable that the cinder may be more basic, and that it may be more abundant. The formation of iron smoke in the Clapp-Griffith converter points in this direction. Unfortunately, there are no analyses on record of the cinder made at Avesta and Prevali. I have analyzed a sample of Clapp-Griffith cinder, made at Pittsburg, and found fifty per cent of silica. This is about the composition of some Neuberg cinders, but is much less silicious than cinders made at Bethlehem some years ago, as given in a paper by Mr. King, read before the American Institute of Mining Engineers, August, 1880.

Whatever may be the cause of the low silicon, it is certainly connected directly with the composition and amount of the cinder on the one hand, and the temperature of the vessel on the other. Now, while I am in doubt as to the result *per se* of blowing small charges, as regards temperature, I cannot help thinking that it tends to make the slags basic and abundant on account of the ease with which iron is oxidized.

As tending to confirm this view, I will cite an interesting description of the practice at Domnarfvet, in Sweden, some years ago, for which I am indebted to Mr. P. W. Moen, of Worcester, Mass.: —

"Some time ago, at the Domnarfvet Works, in attempting to turn down their converter, the turning arrangement, which was worked by friction, gave out, and the converter was held suspended in such a position that it was necessary to keep on the blast in order to prevent the metal from flowing back into the tuyere holes. It was naturally

of the abandonment of the practice, indicates, too, the excessive oxidation of iron. In the Clapp-Griffith process the practice of tapping off the cinder also tends to increase the oxidation of the iron, and to form more cinder. Now what are the conditions in the regular Bessemer practice under which extra soft metal is made,—metal with carbon and silicon almost completely eliminated? I answer: the employment of pig iron, low in silicon, combined with side-blowing, or over-blowing. The latter, that is, the continuation of the blast after all the carbon has been burned out, necessarily forms oxide of iron, and thus tends, by making the cinder more basic and abundant, to retain all the oxidized silicon.

The conclusion seems inevitable that we can make ingot iron in the large converter that is as soft and ductile in every respect as in the small converter, by conforming to the conditions of the small converter; but we must, I think, admit that in the blowing of small charges the conditions for the production of soft metal are *inherent*, and that it may be fairly said that the Little Bessemer has merit of producing extra soft metal, because it cannot help it.

The pig irons thus far used in Europe in the Little Bessemer have been exclusively those used in the regular process. But in the Clapp-Griffith converter, in this country, pig irons, high in phosphorus. have been experimented on, and have given a metal of unexpected ductility. As the result of these experiments, it has been claimed that phosphoric irons can be successfully treated by this process. In Mr. Hunt's paper, already alluded to, he speaks of a shovel made from Clapp-Griffith metal, which had been turned over, and a perfect weld made. This steel contained: carbon, 0.11; silicon, 0.014; sulphur, 0.126; phosphorus, 0.346; manganese, 0.53. Steel, containing carbon, .08; silicon, .01; sulphur, .09; phosphorus, .50; manganese, .48, had the following physical properties: —

Tensile strength.	Elastic limit.	Elongation.	Reduction of area.
80,170	60,240	23 per ct.	32 per ct.
Lbs. per sq. in.	Lbs. per sq. in.		

These results are surprising and unexpected. It is true the metal is rigid, but it is more ductile than one would think such highly phosphoric metal could be. In seeking for a cause for the unex-

It is a matter of history, which is constantly repeating itself, that extravagant claims for new processes in iron or steel metallurgy meet in a surprising degree with a ready and hearty acceptance. All industrial processes begin and end in the matter of cost and value of product, and yet it often takes a costly experience to convince men of facts which are already at hand if they would but see them. In the early statements of the Clapp-Griffith process, criticism seemed to be silenced by the announcement of its dazzling results. The only analytical discussion that the process has yet had we owe to Mr. H. M. Howe, of this Society, who, by his article in *Science*, and in his remarks in the meetings of the American Institute of Mining Engineers, has done much to place the process in its true position. In classifying it as I have done, as simply a variation of the Little Bessemer, I think I have done the process no injustice, although it does differ in plant and practice from the Avesta process. But it seems to me that no new principles are involved in these differences. Whatever may be the final and practical outcome of blowing small charges, the discussion and investigation to which it has given rise will certainly add much to our knowledge of the Bessemer process, and enable us more completely to control the operation.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

ABSTRACT OF THE

Proceedings of the Society of Arts,

WITH LIST OF OFFICERS AND MEMBERS,

FOR THE TWENTY-FIFTH YEAR.

1886–1887.

MEETINGS 350 TO 363 INCLUSIVE.

BOSTON:
W. J. SCHOFIELD, PRINTER, 105 SUMMER STREET.
1887.

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CONTENTS.

NOTICE.

The SOCIETY OF ARTS, established in conformity with the plan of the Massachusetts Institute of Technology, as set forth in the act of incorporation, April, 1861, held its first meeting on April 8, 1862.

The objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement in connection with arts, agriculture, manufactures, and commerce.

Regular meetings are held semi-monthly from October to May, inclusive, in the Institute building; and at each meeting communications are presented on some subjects germane to the objects of the Society, as stated above.

The present volume contains the abstracts of the communications made during the year ending October 1, 1887, most of the business portions of the records being omitted.

For the opinions advanced by any of the speakers the Society assumes no responsibility.

LINUS FAUNCE,
SECRETARY.

BOSTON, June, 1887.

PROCEEDINGS OF THE SOCIETY OF ARTS

FOR THE TWENTY-FIFTH YEAR.

MEETING 350.

Steel for Warfare.

BY MR. H. M. HOWE.

The 350th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, October 14, 1886, at 8 P. M., Prof. T. M. Drown in the chair.

After the reading of the minutes of the previous meeting, and the election of new members, the chairman introduced MR. H. M. HOWE, who read a paper on "Steel for Warfare."

Mr. Howe first described what steel was, and showed by diagrams the effect of varying proportions of carbon on certain of the physical properties of iron. The tensile strength increases with the carbon, reaches a maximum, and again declines. The hardness also increases with the carbon, but it does not reach its maximum as soon as the tensile strength does. The property of being rendered alternately hard and malleable by rapid and slow cooling also increases with the carbon, reaches a maximum, and declines. The ductility, however, decreases as the carbon increases; and the melting point of the metal rapidly falls. The region of high ductility is one of great infusibility, and it is only within a few years that these ductile irons could be melted, and consequently the intermingled slag be removed.

The presence or absence of this mechanically intermingled slag marks the only difference between ordinary wrought iron and steels low in carbon. The steel of today offers the engineer an enormous

of carbon, which is decidedly stronger and less ductile than boiler-plate steel, as best suited to great guns.

Finally, as to armor plate. There are several kinds employed. Chilled cast-iron armor, such as Gruson's, is intensely hard, but as intensely brittle; hence it requires enormous thickness, with corresponding enormous weight, to resist successfully the impact of a great projectile. For land fortifications probably nothing can compare with these plates, but they are manifestly unsuited for the armor of war vessels.

Wrought-iron armor has so much less resisting power than steel of equal weight and thickness that it may be considered as out of the race.

Steel plates are of two kinds,—solid steel plates, which are homogeneous, and compound steel-faced plates with a hard steel face and a back of tough wrought iron or soft steel welded to the face. The armor plate must be hard enough to stop the projectile, and tough enough not to be shattered by its blow. The combination of hardness and toughness the compound steel-faced plate attempts to attain by the simple and promising expedient of welding a steel face so hard that the projectile cannot enter it to a backing so tough that the blow cannot shatter it. For such a face we apparently need great strength and hardness. In twelve recent instances the highest carbon which I find is 0.97 per cent, the lowest is 0.56 per cent, and the average is 0.70 per cent. In solid steel armor we need much greater ductility. The famous solid armor made by Schneider of Le Creusôt, has 0.43 per cent of carbon. This composition gives about the highest combination of strength and ductility.

When put to direct competitive test, the steel-faced plate has not shown as much resisting power as the solid steel plate. While in some trials at St. Petersburg the steel-faced plate came out rather better than its competitor, in the famous Spezia trials, as well as in those at Copenhagen, the solid steel showed by far the greater resisting power. The resisting power of the steel-faced plate may possibly be greatly increased, however, by altering the relative thickness of the steel and iron (at present about one-third of the thickness is of steel), by varying the ductility and hardness of its components, etc. There is one source of weakness, however, which is not likely to be removed. A plane of weakness, along which separation readily takes place, occurs at the junction of the steel and iron, even though they be actu-

the kneading, the rubbing, and pressing together of the particles which takes place in forging.

Rolling is by far the cheapest method of forging. It consists of squeezing the piece which is being forged between a pair of horizontal cylinders. The effect of rolling on the quality of the steel is quite as beneficial as that of either of the other methods of forging. For the manufacture of plates nothing can compete with the rolls in cheapness and efficiency. The use of the rolls is restricted by the fact that we can only produce in them pieces whose cross section is uniform or nearly so.

The hammer offers the great advantage over the rolls that we can forge under it pieces of very irregular shape, but it, too, has a serious limitation in the fact that the effect of its blow is chiefly external. The distending effect of the blow on the interior of the mass is much less than on the exterior. Even the enormous hammers of Europe, the weight of whose falling parts rises to eighty tons, appear insufficient for thoroughly working large masses like great guns.

The largest American hammer, I believe, belongs to Park, Bro. & Company at Pittsburg, and weighs only 17 tons. Engineers often say that its effect equals that of a European 50-ton hammer, since its fall is accelerated by the pressure of steam on the upper surface of the ram which forms the hammer. But a moment's reflection shows the effect of the steam is simply to accelerate the fall of the hammer as a higher fall would, and we still have a mass which is light compared with the great European hammers, though indeed falling at great speed. But no speed will give a bullet the effect of a 1000-pound shot, and the high velocity of the Pittsburg hammer cannot compensate for its lack of mass in forging heavy pieces. Its blow remains a swift tap compared with that of a 100-ton hammer.

In forging under the hydraulic press, the lump of hot and plastic steel is placed in a mold whose interior has the shape which the exterior of the finished piece is to have, and a stamp, shaped so as to give the upper side of the piece the desired form is pressed down on it by hydraulic pressure. While the blow of a hammer chiefly distends the exterior of the piece struck, the slow, continued pressure of the hydraulic press works on interior and exterior alike, and forces the steel into every crevice of the mold like so much butter. There can be no question that for forging masses like great guns nothing can compete with the hydraulic press.

in its preparation, it solidifies without evolving gas. The Terre-Noire process, by preventing the loss of continuity caused by blow-holes, raises the tensile strength of the metal, probably without lowering its ductility; indeed, it appears to raise the ductility of steel as well as its tensile strength. It greatly lessens the advantages to be gained by forging. The engineers of Terre-Noire believe that with further experience they will produce castings whose quality will equal that of the best forgings, and of course at much lower cost.

We come next to the Rodman principle of gun manufacture. It consists in casting the gun around a water-cooled central core; the water circulating through the core rapidly abstracts the heat from the molten iron, and soon a thin cylinder of metal solidifies in contact with the core. Around this a second layer quickly solidifies, and on cooling powerfully compresses the layer within it. A third layer solidifies in turn and compresses the layer within it, and so on; thus, when powder explodes within its chambers, the whole mass of the gun instantly resists its expansive force, and we get the effect which is produced in built-up steel and wrought-iron guns by shrinking successive jackets around a central tube.

Eminent engineers who applied this principle to cast-iron guns very effectively during the war of the Rebellion are strongly of the opinion that it can be successfully applied to steel. Of course, this can only be proved by actual experiment.

The combination of this principle with the Terre-Noire process may be expected to produce an excellent gun, and one which could be turned out at comparatively small cost, and with great rapidity. This might be a matter of prime importance to us. A long time would be required to erect the enormous machinery needed for forging great guns, and after its erection the time required to forge, temper, fit, and assemble the pieces of a built-up gun would be very much greater than that needed for simply casting on Rodman's principle and boring.

In the matter of tempering, sudden cooling increases the hardness of steel at the expense of its ductility. The effect on tensile strength and ductility depends on the suddenness of the cooling, which in turn depends on the initial temperature of the piece to be cooled, and of the bath in which it is immersed, and of the specific gravity, mobility, specific heat, and latent heat of gasification of that bath. Immersion in mercury which is very dense and mobile causes very

many respects do them better; but this is due to the fact that we naturally profit by their experience, and also at the present time no one man does the whole of anything, hence he can do his particular part better.

In many branches, however, we have made but little, if any, advancement. This is particularly the case in the matter of location, where we seem to have copied the earlier engineers in their errors, but not in their habits of careful observation and study. The majority of our railroads are uneconomically located, and not only was the first cost of construction more than it ought to have been, but the loss in the operating expenses is enormous, and increases with increasing business. This loss is not, in the majority of cases, due entirely to the engineering profession, but to the mistaken policy on the part of the management of the railroad companies.

The expenses of the engineering parties on preliminary work and final location are very great, and for much of this expense the management can see no direct return, and there seems to be an idea abroad that most of the money spent in this way goes for theory, and is of very little practical use to the company. Therefore, the salary of the locating engineer is comparatively small, and his ability is frequently small in proportion. The number of his assistants is kept as low as possible, and the result is inferior work. The vital principles upon which the economic location of a railroad depends are not considered at all, or, at the most, in a very slight degree, and the smaller details upon which, to a great extent, depends the ultimate financial success of the road are left entirely out of account.

After the road is located, the management secures the services of the best construction engineer possible. This is as it should be; but no matter how great may be the abilities of the construction engineer, or how much he may save in overcoming the defects in location, still the greater part of the money merely passes through his hands as a paymaster, having been actually expended months before by the locating engineer.

In order that the railroad engineer of the future may be thoroughly competent, both in the "theory of economic location," and in the details connected with the work in the field, too much attention cannot be paid to this branch of education.

We are in an age of specialities. The engineering profession has

Let us now look at some of the items that should be included in a course of instruction in "railway science," or as it is commonly called a "special course for railway engineers." The length of the course should, if possible, be five years instead of four. The first two years should be devoted to laying a firm foundation in the general studies, particular attention being paid to mathematics, chemistry, and physics in their more elementary forms. The third year to the general study of civil engineering, and the last two years to a special study of railroads in all their branches. The third year's course should contain thorough instruction and practice in the field work of the railway engineer, in both location and construction. When the weather will permit, the field work should be pushed even to the point of sacrificing some of the work in the class room. The field methods should be taught exactly as they are now used in the best practice; the same terms used, the same organization of parties, and, most of all, the same discipline and strict attention to business. The greatest possible attention should be paid to the subject of location, in all its details in the field, and when the student has mastered as far as possible the principles that govern a railroad location in regard to the geography of the country, and understands the actual work of putting the line on the ground, then and not till then should he be instructed in those finer details and principles of the work called the "Theory of Economic Location," and upon which the true location of a railroad depends.

This "Theory of Economic Location" should be taught in the last two years. Also, there should be given a course of instruction in every branch of railroad construction, which should contain an amount of hydraulic and sanitary engineering sufficient to enable the person to build and maintain stations, shops, etc., and the proper handling of all the water that may be encountered in the construction and maintenance of the road; the "maintenance of way" in all its details, both in theory and practice; the proper management and economical distribution of large and small gangs of laborers; railway management as it applies to the operating of the road, such as internal management of the separate departments and their relations to the general management; the making up and running of trains; running and repairs of locomotives and rolling stock; station and terminal service; the relation between the railroad and the public; the finan-

possible. It teaches him to think and to express his thoughts in a clear, logical, and grammatical manner.

He should be taught habits of application and the power of being able to concentrate the whole mind for the time being upon whatever work he has in hand. In other words, he should be taught to study, so that when he leaves he will not only be able to profit by his own experience as it comes slowly, but, what is far better, to profit by the experience of others, and thus at once advance to a point which it would take him years to reach by himself.

During the years spent at the Institute the student should examine as much as possible all engineering works that can in any way interest him while in process of construction.

In conclusion, let me say that the student should be so drilled that when he graduates he can have not only the diploma of the school, but, what is of more importance to him, can accept any position in his profession that offers, prove himself of use, and therefore a necessity to his employer, and earn a living for himself.

Prof. SWAIN, in the discussion which followed, spoke of the new field opening now to civil engineers in the actual management of railroads, and the consequent change in the instruction required. No line should be drawn between theory and practice. Theory should depend on practice, and in practice the necessary theory should be properly recognized.

Mr. G. R. HARDY, of the Boston & Albany railroad, after calling attention to the vast increase in railroads during the last fifty years, and the great dependence of our people upon them, remarked the ignorance of a majority of people on the geography of the principal roads. Instead of the well-worn question in our school geographies as how to get from Montreal to St. Louis by water, why not ask: "By what roads can the western grain be transported to the places of export?"

Mr. DWIGHT PORTER spoke of the tendency of civil engineers at the present day to enter more and more into the actual management of a road, and cited President Roberts of the Pennsylvania as a noted example.

Gen. WALKER advocated economy as one of the most important qualifications of a successful engineering career. Practical handling of materials one's self is surely conducive to economy. The English scientific schools are following our lead and introducing manual training more and more.

HON. JACOB A. DRESSER queried whether England or America is ahead in scientific management of railroads. The conditions in the two countries are entirely different. There, small distances and plenty of capital; here, immense distances, and capital not so plenty.

MEETING 352.

Incandescent Lighting from Arc-Light Circuits.

BY MR. FRANK RIDLON.

Domestic Manufacture of Carbonated Beverages.

BY MR. CHARLES E. AVERY.

The 352nd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, November 11th, at 8 P. M., Prof. C. R. Cross in the chair.

After the reading of the records of the previous meeting, and the election of new members, the chairman introduced Mr. Frank Ridlon, of the Brush Electric Light Company, who read a paper on "Incandescent Lighting from Arc-Light Circuits."

Mr. RIDLON said: In the past there has been a great gulf fixed between arc-lighting, so called, and incandescent lighting, the supporters of high and low tension, respectively, having no dealings with the opposite faction, knowing comparatively little and caring less about the respective merits of the two systems. This gulf is now bridged, and high tension and low tension may shake hands across the "bloody chasm." The merits of the two methods are combined, without the deficiencies of either. The great advantage of high tension is the fact that the current can be conveyed a long distance with a moderate cost for conductors; the advantage of low tension is its freedom from danger to human life.

In the new system of incandescent lighting from high tension currents, the high tension is used to convey the current along the line to the points at which it is wanted, while, where it is introduced into a dwelling house, or store, or other places where persons may have access to it, it is of low tension.

Now it is probably not necessary for me to explain to you how the ordinary arc and incandescent circuits are run. In the first, you will remember, the lights are strung along, one after another, like birds sitting on a rail, while incandescent lamps are interposed between two main conductors, like the rungs of a ladder. In the new system we have a combination of the two,— what is known as multiple series. This arrangement resembles a number of ladders in series, or one following the other,— the current passing along the line until it reaches one side of the ladder, then across the rungs of the ladder, or the incandescent lamps, to the other side-piece of the ladder, and then on to the line until it meets another ladder or set of lamps, and so on until the other side of the dynamo machine to that from whence it started is reached. It will thus be seen that the total current generated by the machine, whether 8, 10, 12, or 20 amperes, will pass through these rungs of the ladder, or lamps, which must, therefore, be of sufficient number and capacity to carry that current. The usual number of 16-candle-power lamps hitherto has been from seven to nine. For the sake of illustration and simplicity, let us assume a 10-ampere current, and ten lamps in each multiple, each requiring one ampere of current, and, say, 50 volts of electro-motive force. Now, as long as these ten lamps are perfect, each will carry its due proportion of current, and all will go well. But suppose one of these lamps to break, either from accident or old age, what follows? That lamp, of course, being unable to carry its proper quota of current, the remaining lamps have to carry it if it is not elsewhere provided for; and the means of conveniently and safely providing for it is just what all the endeavors of inventors and others who in the past have attacked this problem have been directed toward devising. And this brings me to the main point of my subject. Consider what the result of leaving such a multiple unprotected would be. When the first lamp gave out, the remaining ones would still have to carry the same current as the whole of them had previously taken, with the result that those lamps would have to carry more than they could safely stand. Another lamp

mouth, N. H., others in New Haven and Bridgeport, Conn., and in many other places, and their number is increasing daily. The practical working of the system is therefore beyond dispute.

To explain the system and circuits fully in a paper like the present would be impossible, and necessitate a number of diagrams; the results, however. I can put before you. The mechanical part consists of a "distributing," or more properly speaking a "protecting," box interposed in the arc-light circuit just as an arc lamp is, and from which are led the wires supplying the incandescent circuit and lamps or motors. This box contains two or more solenoids or regulating electro-magnets, controlling a series of contacts connected with resistances which are individually switched into circuit on the extinction of a lamp.

The circuits are usually arranged to operate 45 to 50 volt lamps, taking about an ampere of current each, and thus allowing of from one to eighteen lamps, there being, when more than nine lamps are in operation at normal incandescence, 90 volts in the circuit of incandescent lamps. In the ordinary box the circuit has to be switched over by the consumer from 45 to 90 volts when he requires more lamps than nine. If, however, the circuit be at 45 volts, and nine lamps are in circuit, switching a tenth lamp in will do no harm, but the current of the machine being constant, the lamps will not have sufficient current supplied to them, and will consequently become dim, thus indicating to the consumer that he should turn on his 90 volt circuit, to do which he has simply to turn a key or handle projecting from the box, which is kept closed and locked to prevent meddling with it. When the tenth lamp (any lamp in the circuit may be the tenth) is turned out again, the box will automatically switch the circuit back to 45 volts, thus saving energy and cutting out the resistances theretofore protecting that part of the circuit.

The whole of the lamps in the group of incandescents may be turned out without injury to the protector or the general circuit, though it would not be economical to do so; when it is desired to turn out all the lights, for the night or otherwise, the box is cut out of the circuit, and the current passes by. When it is wished to use large lamps, *i. e.*, 65 or 70 candle-power on a box, they are connected to the two outside wires of the three (No. 12) main lines leading from the box, which is then turned to 90 volts.

multiple more than the pressure necessary to operate the lamps, usually not over 50 volts, which is of course harmless. On this question of safety, the following remarks of Prof. GEO. FORBES are interesting: —

"Now a great deal has been talked about the danger of introducing high pressure in electric distribution. I think that I shall find general agreement among competent people when I say that a great deal of what has been talked in this way is pure nonsense, and that high pressures are not in the least more dangerous than our present systems of illumination; that if we have to bring high pressure of electricity through a district, those pressures are confined to the wires, and it is only in the case where there is disgraceful negligence of duty, and a disgraceful leakage towards the earth in some part of the system, that it is possible for anybody to receive a dangerous shock from the wires of such a system. The wires which conduct the electricity into a house of any of these high potential schemes can never have a greater difference of pressure between them than what is required for the lamp; that is, in the present state of affairs, something like 100 volts. We will say that is the highest pressure there can exist between the two wires, and it seems almost incredible that there should ever be allowed to be a leak in the system so great that when a person touches one of the wires he should have a high current flowing through his person which would be dangerous. If we are to abolish the idea of using high potentials simply because of this vague notion that some time a shock might be experienced, we might as well abolish the whole system of gas lighting, because it is possible that people can go into rooms where there is a leakage of gas with a lighted candle. The danger from gas is infinitely greater than that which can ever come from high potential electricity, and the difficulty of detecting a leakage of gas is likewise infinitely greater than the difficulty of detecting a leakage of electricity. A properly organized system of distribution of electricity at high potential would render a severe shock to any person absolutely impossible, and that is the point which needs to be dwelt on very strongly at present, because so much has been talked about the dangers of high potentials." (Cantor Lectures, Society of Arts, February 16, 1885.)

When the connections to the box are made the circuit is always closed, either through the lamps or the resistances, and to open the

cent system, however, has always been considered as belonging to the category of the "philosopher's stone," and as being too good to be true; but how many of those supposed to be too good things have proved true? how many apparently insuperable difficulties have been overcome, and unsolvable problems have yielded their tardy solution before persistent and ingenious application? May we not, therefore, reasonably look forward in happy anticipation of the time when the ideal high-tension incandescent system shall be known and used in every town and district throughout the country, dispensing its incalculable benefits wherever civilization finds an entrance, illuminating our homes with the purest and sweetest rays that nature has given to man for man's utility?

In the discussion which followed the paper, Mr. C. E. AVERY suggested that the use of the volometer, which indicates a variation of one ten-thousandth of a degree Fahrenheit, might in some way be operated by the increase of heat when one lamp in a multiple failed, and shut off the extra current and turn it back on the line.

Prof. CHARLES R. CROSS said that the Siemens pyrometer might be used in some such way as Mr. Avery suggested for automatic regulation.

Dr. SKINNER remarked that, as the current on the multiple series line must in any event be constant, any such device would have no practical use.

Mr. AVERY replied that he had in mind a circuit carrying an alternating current passing through the secondary of a Ruhmkorff coil, the induced current from the other coil being employed to operate the lamps. In this second circuit such a thermo-regulating device might be used.

Mr. G. W. BLODGETT: How is it possible to run two 16-candle-power incandescent lamps in circuit with arcs without wasting current?

Mr. RIDLON replied that a distribution box for two lamps was provided; if one lamp broke or was turned out, an equivalent resistance was thrown into the circuit. This was accomplished by using lamps suited to the current, two lamps being made to stand the whole current of the line.

Mr. KIMBALL, of Woburn, explained from diagrams the various multiple-series cut-out boxes.

MEETING 353.

The New Art of Electric Welding.

BY PROF. ELIHU THOMSON.

The 353rd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, December 9th, Prof. C. R. Cross in the chair.

After the reading of the minutes of the previous meeting and the election of new members, the chairman introduced Prof. Elihu Thomson, of the Thomson-Houston Electric Company, who read a paper on "The New Art of Electric Welding."

Prof. Thomson said: Hitherto, about the only metals which have been welded with facility by the ordinary method of heating and hammering have been wrought or soft iron, steel. platinum, gold, and a few others. So far as I am aware, cast-iron, brass, gun-metal, and bronze, German silver, zinc, tin, lead, aluminum, and several other metals less commonly used, have not hitherto been welded; and even with copper, which softens readily by heat, the welding together of two pieces, though not impracticable, has been so difficult as to be seldom tried. Much less, indeed, has it been generally practicable to weld pieces of unlike metals together, although a few exceptions exist.

Again, it can be truly said that very small pieces even of iron can scarcely be welded in the ordinary way on account of the rapidity with which they cool or are reduced below the welding temperature.

In electric welding, however, some of the metals which it was before impossible to weld become most easily dealt with; such are cast-iron, brass, and bronze, zinc, tin, etc. Copper, formerly welded with so great difficulty and uncertainty, unites with great ease and certainty. Iron, steel, platinum, and like metals, formerly known as weldable, are with great facility welded electrically. Thus far I have not tried any pieces of the same metal and failed to secure a weld. When, however, the pieces are of different metals or alloys, failure may result from too great differences, either in their temperature of softening or in their specific electrical and heat conductivities.

There is, also, a very wide field of usefulness to be found in the manufacture and repair of tools and machinery.

As examples of such work I may mention the lengthening of screw-taps, drills, reamers, augers to any desired degree; welding new drills and reamers to the taper shanks of old and worn out drills and reamers; and in general welding steel pieces to steel or wrought iron, or even cast iron, bodies of tools.

I have united the ends of wires less than .02 of an inch in diameter, and the larger size of pieces dealt with has been only limited by the power of the apparatus at command. I have reason to think that the actual fuel consumed in effecting a weld by electricity is less than in the ordinary furnace processes, and this is due to the very small time consumed in the operation, the application of the heat to the metal only at the weld, and the consequent very small loss by radiation and conduction during the operation. The pieces are not required to be manipulated during the process, a great advantage in the working of large pieces.

Having thus reviewed the possible applications as they now present themselves, let us turn to the operation itself.

In electric welding the energy given by fifty thousand amperes of current and half of a volt will weld a bar of steel or iron of about an inch and a half in diameter, so far as I have been able to estimate the conditions. There is quite a difference between the way the power is used in running electric lights and in welding. Lights demand the power continuously, while in welding the energy is demanded for a comparatively short time, varying from a few seconds to a half minute or thereabouts.

The apparatus here presented to the notice of the Society will now be described. The smaller apparatus consists of an induction coil composed of a core of iron wire about twelve inches long, and two and one-half inches in diameter, around which has been wound a coil of primary wire, and outside of that a coil of sixty-four wires, No. 10, laid parallel, and passing only eight times around the core. The ends of the secondary strands so formed are bolted down to copper plates, upon which the clamps for holding the pieces to be welded are mounted. These clamps are formed at the upper part of comparatively heavy blocks of metal. One of those blocks is arranged to slide upon its copper bed plate, and is guided so as to move in a straight line towards the other

small percentage of loss. A current of a little over 20 amperes and 600 volts in the primary may produce in the secondary nearly one volt and 12,000 amperes.

There should be provision made by suitable switches to cut off the current from the pieces which are welded when the weld is known to be complete. This could be done, of course, by breaking the circuit of the secondary coil itself at the proper moment, but it is evident that for such large currents the switch would have to be very massive. Equally good results are obtained by cutting off the primary current, or by breaking the circuit of the dynamo.

To make an electric weld the pieces are rubbed bright near the ends to be joined so as to make good contact with the clamps by which the current enters; they are then placed in the clamps with their ends abutted in the free space between the clamps. The ends are of course clean, so as to form good contact, after which in most cases a little powdered borax is applied to the joint to act as a flux, or if the metal be of low melting point, as tin or lead, a little zinc chloride or tallow is applied.

It is of course best to have the clamps formed to fit the pieces, especially when they are of irregular outline; but for round or square work simple V grooves in the clamps suffice to hold the pieces in place and give the requisite contact.

When the pieces are in place and pressed together by the means provided, the current is turned on, and at once the ends of the bars heat at the junction, a slight yielding or approach of the pieces takes place, and before the operation could be described in words the work is done. Sometimes the joint is hammered to still further perfect and consolidate the weld.

Whether the electric current has any peculiar action in assisting the welding, I do not know, but am inclined to think that in some cases it has some such influence, although much the larger part of the work is the simple result of heat, I presume. One circumstance, however, arising out of the electrical properties of the metals dealt with may be noticed. This is the tendency to a uniform heating of the section of the bars abutted, as a consequence of the fact that cold metal is a better conductor than hot, and that, therefore, any cooler line of particles at once becomes the path for increased current, and is brought up in temperature to equality with the rest. I would call

MEETING 354.

Stellar Photography.

BY PROF. E. C. PICKERING.

The 354th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, December 23rd, at 8 P. M., Prof. C. R. Cross in the chair.

After the reading of the minutes of the previous meeting, the chairman introduced Prof. E. C. Pickering, director of Harvard College Observatory, who read a paper on "Stellar Photography."

Prof. PICKERING said: The qualifications required for an astronomer have varied greatly in different times. In the early days an astronomer was often a metaphysician who paid little attention to the stars. Later came the mathematical era. Then, with improved instruments, some mechanical skill was required. To use a large reflector, an astronomer must almost become a mechanical engineer. The spectroscope and photometer rendered a knowledge of physics essential. Now the question may be asked whether the astronomer of the future will not be a photographer.

Stellar photography is largely an American science. It originated in 1850 in a daguerreotype taken at the Harvard College Observatory, under the direction of Prof. William C. Bond. In 1857 Prof. George P. Bond again took up the subject under much more favorable conditions. His three classic memoirs on the subject render him the father of stellar photography. He showed that the position and brightness of the stars could be determined with great precision by this method. An elaborate study of the subject was made later by Mr. L. M. Rutherford, whose results unfortunately are mainly unpublished.

Dr. Gould, also, in South America, accumulated a large collection of photographs of star clusters and other objects of interest in the southern heavens. The work of Mr. De la Rue, of Dr. Draper, of Mr. Common, and of the brothers Henry was next described. The last named gentlemen have far surpassed their predecessors in the beauty of the maps they have constructed.

which the work described above has been done, an eleven-inch telescope has been lent by Mrs. Draper, and mounted in the most approved manner. Four prisms, the largest eleven inches square, have been placed in front of the telescope, furnishing the finest piece of apparatus for the purpose ever constructed. All the instrumental work has been furnished by Alvan Clark & Sons. It is doubtful if it could otherwise have been obtained.

An assistant in the Observatory, Mr. Gerrish, devotes his entire time to this work. Three lady computers are engaged on the measurements and reduction of the photographs.

Three extensive investigations are now in progress. The first has secured photographs of the spectra of all stars visible to the naked eye in Cambridge. To avoid possible omissions, this work is to be repeated during the coming year. An exposure of five minutes is given to each spectrum, and a hundred or more are sometimes obtained upon a single plate. About six thousand spectra have already been measured and identified.

The second research relates to the fainter stars, each spectrum receiving an exposure of an hour.

The third investigation is conducted with the large telescope, and relates to the brighter stars.

The progressive improvements were shown, the length of the spectrum being successively increased from about a quarter of an inch to five inches. Large numbers of spectral lines appear in the later photographs, and a wide field is open to the study of the constitution of individual stars; not only is it possible thus to determine their chemical constitution, but probably some evidence will be furnished of the temperature and pressure to which they are subjected, and possibly their age. The motion of the stars towards or away from the earth may also be determined.

A vast field of work is open, and it is believed that the results will furnish the best possible memorial to one of the most skillful and ingenious astronomers that America has yet produced.

the greater certainty of steam or electric yachting. Looking back but a comparatively few years, we find the beginning of the history of yachts and yachting. The first reference to the sport places its introduction in England in the last part of the seventeenth century. In 1800 the number of yachts in England was about fifty. The founding of the Royal Yacht Squadron in 1815, and the prestige thus given this form of amusement, greatly developed the taste for the sport, and from that time on the advancement was rapid, both in numbers and in quality. In 1850, the year before the arrival of the America, there were probably about 500 yachts owned in England. Down to this time the improvement had been in minor details. Some changes for the better had been made in rigging and ballasting, but no marked advancement had been made. The yachts then built were distinguished by their proportion of fore-body or bow to after-body or stern. Much theorizing on this subject was done, and, after the introduction of Scott Russell's wave theory, 3 to 2 was the generally accepted proportion. The Mosquito, and possibly one or two others, were built by this theory, but theory amounted to little in comparison with example, and the arrival of the America was needed to teach by example.

In America the year 1816 marks the introduction of yachting. At that time we were a more maritime nation than at present; that is, a larger proportion of the inhabitants were engaged in seafaring pursuits, and there was a much more universal appreciation of marine affairs. It is not at all strange, then, that the people of the United States should early develop an interest in yachting, or that the famous old town of Salem should be the home port of the first large American yacht. This was Cleopatra's barge, built for Captain George Crowninshield, in 1816, and launched late in the year, or in the first part of 1817. She was a 200-ton yacht, brigantine rigged. As soon as launched, her owner, accompanied by a jolly party, set sail for Europe. This is the first ocean cruise by a yacht on record. In England she naturally attracted much attention, crusing thence down to the Mediterranean. Captain Crowninshield, who was a very eccentric man, had her magnificently refitted at one of the southern ports of France, and then continued his cruise, a band of musicians accompanying him. At every port the yacht was an object of intense interest, and the log-book, which has been preserved, states that it was no uncommon occurrence to receive on board 5000 visitors in a

it advantageous to decrease the beam, and builders would increase the length while decreasing the beam. Mr. Burgess next gave a description, illustrating on the blackboard, of the action of the various forces of wind and wave acting on a moving yacht, showing that the deep boat can keel over to a much greater degree than can the more shallow sloop. Cross sections amidship were drawn, illustrating the position of the centers of gravity and buoyancy in the two classes. In England yacht designing became a scientific profession, while in the United States builders went by the rule of thumb methods. Nevertheless, the ocean race between the Henrietta and Vesta, in 1866, showed that we still had fast and seaworthy boats. In 1867 the Sappho was constructed in New York, and taken to England to sell, relying on the prestige which the America had given our yachts. After a defeat she returned to this country, and was given by Mr. Douglass, her purchaser, into the hands of Captain Bob Fish, a famous designer. Her beam was increased, and she was again sent to England, this time defeating her former antagonist, the Cambria. Not discouraged, the Cambria challenged again, and was again defeated, this time in American waters. The question is often asked why the defence of the cup is entrusted to one vessel, instead of allowing a fleet to compete. This is partially settled by the conditions under which the cup was given, and it would be manifestly unfair for one boat to compete with a fleet, some one of whose scattered members would be sure to obtain advantage of position, etc. The two Canadian yachts, Countess of Dufferin and Atalanta, were the next challengers. They were both easily vanquished, an American schooner taking care of the Countess, and the Mischief winning the other race.

During all this time advances had been going on in England, and development of the fast types, as the Genesta and Galatea, was alarming Americans. In England there are now over 2000 yachts, representing over £4,500,000. The United States probably equals that number, but the tonnage is considerably less.

Until the construction of the most recent yachts, almost the entire attention of Americans was directed toward the development of the schooner type. The Gracie was the only large sloop, and she was a somewhat patched up affair. There were a few cutters owned here, and some other fast boats, but it became evident that something must be done. The Priscilla in New York, and the Puritan in Boston,

resulted. In designing the Puritan, speed in light weather was not the object in view, but it was intended to make her a good all-around yacht. After the defeat of the Genesta by the Puritan, the challenge of the Galatea attracted, of course, much attention. She seemed to shows signs of greater speed, and we became alarmed again, and, as a second result, the Mayflower was built in Boston, and Ellsworth turned out the Atlantic at Brooklyn. The contests of these boats are fresh in the minds of all. In designing the Mayflower there were certain objects in view. The centers of gravity and buoyancy were both made lower, and a longer and easier bow constructed. There were various other minor changes, in the rigging, etc.

In closing, Mr. Burgess said that, while yachting needed no defence as a sport, its advantages were many. Besides serving to keep up the interest of Americans in American ship building, it has an important bearing in naval affairs. The Government has already made inquiries as to the number and speed of such yachts as could be used as despatch or small gunboats, and is having a census made of the available yachting sailors.

At the close of the lecture a large number of stereopticon views were shown, illustrating the essential differences in the sloop and cutter variety, and giving fine views of the various yachts as they have appeared in the races.

The meeting was adjourned after passing a vote of thanks to the speaker for his very interesting lecture.

MEETING 356.

The Use of the Freezing Process for Excavating in Soft Materials.

BY MR. CHARLES SOOYSMITH.

Experimental Comparison of Some Different Methods of Measuring the Flow of Water.

BY PROF. GEORGE F. SWAIN.

The 356th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, January 27th, Hon. J. A. Dresser in the chair.

After the reading of the minutes of the previous meeting, the chairman introduced Mr. Charles Sooysmith, of New York, who read a paper on "The Use of the Freezing Process for Excavating in Soft Materials."

Mr. SOOYSMITH said: The subject on which it is my privilege to address you has become known to engineers as the "Poetsch freezing process." The inventor was Mr. Hermann Poetsch, a German mining engineer of no particular note until he conceived and made a practical success of the method which bears his name. He had something to do with sinking a shaft near Ashersleben, Germany, to a vein of coal, where, after excavating about one hundred feet, a stratum of sand eighteen feet thick, overlying the coal, was encountered. It occurred to Mr. Poetsch that the great difficulty occasioned by the influx of water through the sand could be overcome by solidifying the entire mass by freezing. To accomplish this, he penetrated the sand to be excavated with large pipes sunk entirely through it and a foot or two into the underlying coal. These were placed in a circle at intervals of a meter and close to the periphery of the shaft. They were eight inches in diameter, and closed at the lower end. Inside each of these, extending nearly to the bottom, and open at its lower end, was a pipe but one inch in diameter. This system of pipes was so connected that a closed circulation could be produced down through the small pipes and up through the large ones. An ice machine, such as is used for cooling in breweries, making ice, etc., was set up near by and used to keep at a temperature below zero, F., a tank filled with a solution of chloride of magnesium, the freezing point of which is 40° below zero, F. The solution so cooled was circulated through the system of ground pipes described.

Thermometers were placed in pipes, sunk into the mass of the sand: the temperature of mass before the circulation of cold liquid was started was 51.8 F. The circulation was kept up and the temperature of the mass was rapidly lowered, and, at the point where the temperature was taken, the mass was frozen the third day after circulation had commenced. The freezing took place, of course, soonest about each pipe, beginning first near the bottom, where the inflowing solution was coldest, and extending outward in radial lines. The cylinders, or more correctly speaking, the frustums of cones about the pipes, finally met, thus forming a continuous frozen wall, inside of

water look like sandstone, and seem almost as hard. With pick and shovel, workmen in the bottom of a shaft will do very well if they average an inch in depth per hour. Of course the idea of thawing the interior mass at once suggests itself. Pipes for the circulation of heat could be inserted before freezing. My impression is, however, that blasting will prove the preferable method.

Probably the greatest service which this invention will render will be making practicable the construction of subaqueous tunnels, which could not otherwise be built.

In applying the freezing method to the construction of a tunnel there are a number of ways of arranging the ground pipes. Where the depth of water is not excessive, and where navigation and current in the stream do not bother, it would seem simplest and best to put pipes down from above in vertical or inclined positions, placing them in rows on either side of the proposed excavation. They can be incased in non-conductors of heat, except the portion about which it is desired to freeze. The circumstances where this manner would be practicable will not often occur, but we are more likely to meet with cases like that of the Hudson River tunnel, where the freezing pipes must be put in from the completed portion of the tunnel reaching forward beyond the heading. The problem of managing these pipes has been the occasion of a great deal of study, because the heading must be kept frozen, and pipes for freezing must be kept ahead of this. Then, too, the pipes must be so arranged that they will not interfere with putting in the permanent lining.

The result of my own study on the matter is to place the freezing pipes horizontal and parallel, and in a circle near the periphery of the tunnel, and somewhere from three to six feet apart, as experience shall teach may prove the best distance. The brick lining is kept along pretty close up to the excavation. Back at a convenient distance from the heading, in the finished portion of the tunnel, I would have a frame which can be readily moved forward at intervals. Against this frame will be worked the hydraulic jacks which will be employed to push the pipes forward. Occasional bricks can be temporarily left out of the lining to form offsets which can be used to hold the frame in place. Each of the large pipes would have a small pipe inside, extending nearly to the point where a diaphragm provided with a great number of small holes would form an obstruction to the circula-

of subaqueous tunnels, by sinking them in sections from above, as has frequently been proposed. The chief difficulty in this latter method has always been to make the connection between the sections. To do so by freezing would be readily accomplished by providing the ends of the sections with a pipe running around them outside the tunnel space; then when it is desired to make the joint between two sections, after filling the space between them with mud, this latter could be frozen, thus forming a barrier to the influx of water while the permanent joint would be made. Another application has occurred to me in studying the difficulties that may have to be overcome in building a railroad tunnel between Canada and the United States, under the St. Clair River, where my firm is now driving a small experimental tunnel. Under the deepest portion of the river there is scarcely enough material intervening between the rock and the bottom of the river to leave a safe thickness overhead while the excavation is made. It may be necessary to provide what I may call an immense turtle-back, which could be lowered upon the bottom to serve as a temporary roof. To be effective it should be provided with low, sharp sides, and the entire under surface furnished with channels for the circulation of the cold fluid, so that when lowered upon the bottom of the river the thin roof that would have been dangerous could be converted into a frozen solid, which would perfectly protect the work underneath. Still another application occurs to me in connection with this work. The material at the center line of the proposed large tunnel is such that we anticipate no difficulty whatever in driving the six-foot heading which we are now commencing. Better than the turtle-back I have mentioned, it may be to use this trial tunnel as a means of freezing for a sufficient distance about it to permit the excavation of the large tunnel entirely in frozen material. To do this, a car with coils one or two hundred feet long, *i. e.*, the coil that length, not the pipe, in which the vehicle of cold could be circulated, could be introduced into the small tunnel and kept immediately in front of the excavation while this latter is made and the permanent lining put in. I believe that no difficulty would be found in freezing fifteen or even twenty feet radially out from this small tunnel by using means of ample capacity. Thus it will be seen that the construction of under-water tunnels, one of the most hazardous and expensive kinds of engineering, has a resource of incalculable value in this new method.

plish this, it would only be necessary to lower a coil of pipe into or about the opening, throwing something into the latter to impede the circulation of water, and then circulating the brine and freezing the opening fast. In salt water, it would, of course, take a very low temperature to accomplish the freezing. It would not be difficult to make an ice machine to produce an excessively low temperature. Those now made for commercial purposes can produce a working temperature of at least 15° or 20° below zero F.

An early application of the new process is likely to be made in sinking a shaft to a bed of sulphur discovered several years ago in Louisiana. This occurs at a depth nearly five hundred feet below the surface, and to reach it beds of sand have to be penetrated where the head of water in same is three hundred feet. An effort was made to pass through this, but failed, after an expenditure of, I believe, some two hundred thousand dollars. To sink this shaft, the pipes would either have to be put down the entire length at the start, or else resort would have to be had to some method similar to those mentioned in connection with tunnels; or it might be better to build the upper portion of the shaft so large that near the ends of the first set of pipes put in an offset could be made through which a second set could be inserted.

I have now mentioned the peculiar fitness of the Poetsch method for certain classes of work. The chief difficulty in applying it, where there is any difficulty, will be to insert the pipes properly. This difficulty is likely most often to arise from the presence of boulders or logs in the material to be penetrated. It is true this can be overcome by drilling, but it would be very expensive. There has not yet been sufficient experience obtained to enable us to determine the best sizes of ground pipes, and the maximum space we dare leave between them. Mr. Poetsch has continued to copy his first success, using eight-inch pipes placed about a meter apart. In some cases the pipes have not been sunk exactly as desired, leaving a space five or six feet between them at the bottom; still the frozen mass was continuous. The fact is that the freezing is due to cooling of the entire mass in the vicinity of the pipes, and it would seem more a question of total quantity of cold inserted and distance from the center of application of this than the distance of the point from any individual pipe.

Another possible difficulty that will occur only in rare cases is the

EXPERIMENTAL COMPARISON OF SOME DIFFERENT METHODS OF MEASURING THE FLOW OF WATER.

Prof. GEORGE F. SWAIN, of the Institute, was then introduced, and gave a description of the apparatus used by the students of the Institute for the gauging of water, with the results of some experiments carried out a few years ago.

Leaving out of consideration, he said, cases where the flow of water is gauged by actually measuring,— as in measuring-vessels, or by instruments such as some forms of water-meters,— the quantity of water passing in a given time, the ordinary method of gauging the flow is by finding the area of a certain cross-section of the current, together with the average velocity past that cross-section. But since in any current the velocity is different at different points, instruments must be used which will either enable us to determine the velocity at any given point, or the average velocity in a given vertical line, or in the entire cross-section.

The principal instruments for determining the velocity at any point in a flowing current were the double float and the current meter. The former consists of a large and heavy float, so weighted that it will just sink, suspended to a much smaller upper float, which remains upon the surface. By varying the length of the connecting line, the lower float may be suspended at any desired depth. The current meter consists of a wheel similar to an anemometer, set in motion by the current, and from the number of revolutions in a given time the velocity of the current is determined. Two styles of current meters were shown, in one of which the revolutions were counted electrically above the surface.

The average velocity in a vertical is determined by means of long weighted poles or tubes, which float upright, projecting several inches above the surface, and which give the average velocity in the vertical distance which they occupy. It may also be determined by moving a current meter uniformly from top to bottom; while the average velocity in an entire cross-section of rectangular shape may also be determined by moving the meter diagonally from top to bottom and back, thus crossing the stream, the meter taking a zig-zag course. When the meter is moved up and down in a vertical, the measurement is called a *vertical integration;* when diagonally up and down, a *diagonal inte-*

ratio given by Ellis, the single observations differed widely. The results of the method by which simply the mid-depth velocity is measured would therefore seem unreliable in such flumes as the one experimented upon.

Fourth: The same seemed to be true regarding the method of calculation proposed by Gen. Abbot in the journal of the Franklin Institute, for 1873.

Fifth: Judging of the accuracy of a method by the agreement of successive measurements with each other, it appeared that of the methods with meters the diagonal integration gave the most uniform results (though with a possible difference between successive measurements of at least three per cent), the vertical integration coming next (with a possible error of apparently at least five per cent), and the point measurement next (with a possible difference of at least six per cent).

Sixth: Regarding the effect of the velocity with which the meter is moved in integrating, scarcely any effect was observed with the meter of Fteley and Stearns, at least up to velocities of motion of twenty or thirty per cent of the velocity of the current, any existing effect up to that rate being less than the differences between successive measurements under the same conditions. With the Ellis meter, however, as would be expected from its construction, the effect was apparent in a marked degree when the velocity of integration was as much as fifteen to twenty per cent of the velocity of the current. With the Ellis meter, under favorable conditions, the velocity of integration should be much smaller than with the Fteley and Stearns meter.

Seventh: Measurements with the Fteley and Stearns meter gave results uniformly smaller than those obtained by the tubes, by from one to three per cent. This was probably due to the fact that the meter cannot be accurately held in the plane of the cross-section.

Eighth: Measurements with the Ellis meter also gave results almost uniformly less than those with the tubes, by from one to seven per cent, a result which the speaker could not explain.

Ninth: The method of measurement by tubes, as perfected by Mr. James B. Francis, is by far the most accurate method in flumes such as the one experimented on.

In closing, the speaker again remarked that these results should only be looked upon as *indications*, since the number of experiments

source here considered, is indicated by the lack of published information upon the subject. Geological and agricultural reports are common, but only one State, Maine, has made any effort worthy the name to set forth the advantages offered in the way of water power. In the Government census of 1870, statistics of power used in manufacturing appear for the first time. Ten years later the work was carried much farther, and an investigation was made, so far as time and means would allow, into the condition of the water power interests of the country, and into the number and location of important sites remaining undeveloped. The facts here presented and the conclusions drawn are based mainly upon the results of that inquiry, and would doubtless require to be modified somewhat to suit them to the present time.

The use of water power in this country began, as might be supposed, early in its colonial history. Lumber was wanted for building, and grain must be ground for food, and the operations thus involved gave the earliest employment to power. At first, wind power and the power of cattle and horses were frequently utilized, but water power soon became introduced, and was regarded with great favor because of the large amount of work that could be done with its aid. There were water mills in the vicinity of Boston before 1640, and within thirty or forty years from that time they had come into general use in the northern colonies. With the development of other branches of manufacturing the application of water power correspondingly increased. The manufacture of paper was introduced in Pennsylvania nearly two hundred years ago; and a century later in Rhode Island water power began to be utilized in the manufacture of cotton goods, and probably at about the same time in that of woolen cloth.

From the beginnings thus briefly traced the employment of water power in the various industries to which it is applied has steadily advanced. From time to time the most desirable sites, usually at first occupied by some unimportant saw or grist mill, have been taken possession of by water power and manufacturing companies, and famous industrial centers have here and there become established. What may be called the great powers, such as those at Lowell, Lawrence, Lewiston, Holyoke, Cohoes, and Minneapolis, have mostly been founded, or at least have begun their noteworthy history, since 1825, and several of them since 1850. At Rochester the Genesee River was called into service a century ago.

mouth to 20 inches in central Kansas, and even to 8 or 10 inches in Wyoming, and at many points five or six times as much is recorded in summer as in winter. Timber similarly decreases in amount, soon is confined to light fringes along the streams, and then disappears altogether until the mountains are reached. The dry westerly winds greadily suck up the moisture from the surface, and the streams, which in midsummer are swollen by heavy rains, rapidly afterward sink away to insignificant size, and even the Arkansas and Platte, the latter the largest tributary of the Missouri in point of area drained, have been known entirely to disappear in their sandy beds.

The second essential of a good power has been mentioned as the possession of concentrated fall. In the northern Atlantic States the hard granitic rocks compel the streams to accomplish much of their descent in sudden leaps and plunges, while farther south the rivers have been more successful in wearing down the surface material, and the fall is more uniform. In New England the fall obtained at the larger developed powers ranges in general from 30 to 60 feet. In New York State, owing to a different geological formation, concentrated falls of greater amount are not uncommon; as examples of which may be cited the abrupt pitch of 160 feet at the Niagara Falls, the descent of over 100 feet at Cohoes, and the many fine falls on the Hudson and Genesee Rivers. The latter stream on its way to Lake Ontario hurries down in a wonderful series of leaps,—three at Portage, covering an aggregate fall of 266 feet, and three more at Rochester, 60 miles below, amounting to 205 feet, with 60 or 70 feet of additional fall in rapids at each of these localities.

The streams of the southern Atlantic and eastern Gulf States have perhaps as large average slope as the more northerly rivers, but they accomplish this descent in rapids rather than in abrupt falls. Thus, at the great falls of the Catawba River, in South Carolina, there is a total descent of 100 feet, more or less, but it is scattered over a distance of a couple of miles. Similarly at the Narrows of the Yadkin, in the lower Coosa River, and in the Chattahoochee at Columbus, Georgia, are falls ranging in the different localities mentioned, from 80 to 120 feet, but in each case they are dispersed over several miles of river. The Tallassee Falls, in Alabama, are perhaps the finest, considering the volume of water at command, to be found anywhere in the section under consideration, the Tallapoosa River there dash-

twenty-six feet at the most favorable stage of water; but it is so much diminished, and for so long a time, by high water, and any water power improvements must be so subordinated to the interests of navigation, that the employment of the power is hardly probable, though several plans to that end have been proposed.

The command of suitable conveniences for transportation is evidently essential to a good manufacturing site, and lack of these is the greatest bar to the development of many water powers. The value of those sites enjoying water communication has always been recognized, and such have been among the first to come into use. North of the Susquehanna there are but two streams of importance — the Penobscot and Presumpscot Rivers in Maine — on which there is still an undeveloped fall at the head of tide-water or of navigation. The narrow valleys, and rugged intervening country, of New England have forced the railroad lines there to the convenient vicinity of the streams; but in other portions of the country the railroads are found at considerable intervals from the courses of the streams, sometimes even traverse the divides, and in many cases cross the streams at a large angle, leaving intermediate sections without rail connections.

Having examined into the conditions necessary to the successful general development of water power, and noticed the degree in which those conditions are realized in different sections, it is in order to inquire into the extent to which utilization of the streams has actually taken place, and into the changes that have occurred within the period for which authentic data are at hand. That period does not reach back of 1870, at which time about 1,130,000 horse-power of water wheels was in use in this country. By 1880 there had been a net increase of between eight and nine per cent, or to 1,225,000 horse-power, the distribution of which it is interesting to notice. As would be expected, the main utilization is found to be upon the northern Atlantic slope.— the New England States, New York, and Pennsylvania together employing 61.4 per cent of the total power. New York takes the lead with 17.9 per cent, and Massachusetts is second with 11.3 per cent. The Connecticut River, with its tributaries, furnishes the greatest utilized power for a single river system; the Merrimac ranks next, and the Hudson third. In proportion to the extent of country drained, however, the Blackstone River does greater work than any other stream of equal size in the United States. A compari-

2,185,000 horse-power, had been made by 1880. In every important industry in which water power is largely employed, a relatively greater amount of steam power was in use at the end of the decade than at its beginning. The causes which have led to this result form an interesting study in themselves, but their discussion will not be attempted in this paper.

MEETING 358.

The Bessemerizing of Copper Mattes.

BY DR. E. D. PETERS, JR.

The 358th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, February 24th, President Walker in the chair.

After the reading of the minutes of the previous meeting, the President introduced Dr. E. D. Peters, Jr., of Walpole, who spoke on the "Bessemerizing of Copper Mattes."

Dr. PETERS said: Despite the technicality of my subject, the process that I am about to describe has a claim to the attention of the general public as being a close counterpart of the steel Bessemer process which has so entirely revolutionized the iron industry.

But before you can at all appreciate the advantages possessed by this new method of treating copper ores, it is absolutely necessary that you should have a tolerably clear idea of the ordinary methods in use all over the world.

[Here the speaker gave a brief description of the ordinary furnace processes used in smelting copper ores, following the metal to the stage of blister-copper, which is the same product as that derived from the Bessemerizing method.]

Having now some idea of the long and complicated operations required to produce metallic copper from its sulphide ores, you can better appreciate the rapidity and simplicity of the new method.

I will not go into the history of this invention. Many noted metallurgists have had a strong faith in the possibility of applying the

placing the tuyères in a horizontal circle, two inches above the bottom of the converter, so that an opportunity is given for the metallic copper to collect in an undisturbed pool, below the influence of the blast, which still continues its oxidizing duties until the last particle of sulphide is decomposed, and the metal just reaches the level of the tuyères, when it is poured into moulds.

This horizontal placing of the tuyères was virtually the key to success, and after enumerating these few modifications there remains but little to describe to those familar with the genuine Bessemer process.

The difficulties arising when treating low-grade mattes, from the excessive formation of slag and the minute volume of the metallic product, are simply met by dividing the operation into two stages.

Assuming a twenty per cent matte to be under treatment; it is melted in a small cupola and run into the converter, where it is blown until its grade is increased to about sixty-five per cent, the slag being poured off once during the blowing, if it threatens to become troublesome.

When the charge has become nearly a pure subsulphide of copper (sixty-five to seventy per cent), the converter is turned down, and its entire contents poured into a large iron kettle on wheels. The slag, which forms a cake on top, and contains one or two per cent of copper, makes a most welcome flux for the ore smelting, while the cone of rich matte is laid one side till 20 or 30 tons accumulate, when it is remelted in a cupola, again run into the converter, and blown till it becomes blister-copper,— ninety-six to ninety-nine per cent.

An ordinary "blow" takes from twenty to forty minutes, so that allowing for changes, delays, etc., 25 to 30 blows of 2000 pounds each are made in twenty-four hours.

The converters are, of course, very much smaller and lighter than those used in steel manufacture, which hold 6 to 10 tons, and are lined with crushed quartz, to which is added just sufficient plastic fire-clay to make it hold together. After putting in a bottom several inches thick, an ordinary oil barrel is placed erect upon it, and the mixture rammed about this pattern, thinning out to almost nothing at the throat.

A battery of converters consists of three, of which one is in use, one undergoing repairs, and the third drying, ready for use.

of these impurities to seriously impair the quality of the refined copper made from it by ordinary methods.

The future of the Bessemerizing process depends largely upon the policy of those who claim to control it in this country. At present, it is only used at the Parrot company's works in Montana; but we are informed that great improvements have been made, and it is probable that before long efforts will be made to introduce it at other points, where expensive fuel and low-grade sulphide ores demand something cheaper than the ordinary methods.

Prof. T. Egleston has published a paper in *The Columbia College Quarterly Magazine*, giving about all details that are yet known regarding the practical working of this process.

The meeting closed with a vote of thanks to the speaker.

MEETING 359.

Coal Mining.

BY MR. STUART M. BUCK.

The 359th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, March 10th, Mr. H. M. Howe in the chair.

After the reading of the minutes of the previous meeting, the chairman introduced Mr. Stuart M. Buck, of West Virginia, who read a paper on "Coal Mining; with a review of the more recent experiments on the action of dust in colliery explosions."

Mr. BUCK first described the different kinds of coal, giving their chemical composition, physical properties, etc. He then took up the general system of working coal mines, illustrated by blackboard sketches. The entries to the mine are driven in pairs for the sake of ventilation, and they are usually from eight to twelve feet in width, and separated by pillars of solid coal about 30 feet thick. These pillars are broken through by narrow cross-cuts, at intervals of from 100 to 150 feet (the old break-throughs being closed as soon as new ones

of the low specific gravity, it collects most readily near the roof of the mine, but speedily mixes with the air through diffusion. It is detected when in small amount by its effect on the flame of the safety lamp; two per cent is the smallest amount that can be detected with an ordinary lamp, the flame increasing in length and size with the amount of gas. The mixture first becomes explosive when there is six and two-thirds per cent of gas; it is most explosive at ten per cent; and at fifteen and a half per cent it ceases to be explosive and extinguishes the light.

The peculiar principle of the safety lamp was discovered in 1815 by George Stephenson, and also by Sir Humphrey Davy. This principle is that the encasing wire gauze so far cools the burning gas within that the flame does not communicate with the surrounding explosive mixture. This is true so long as every lamp is in perfect condition and there is no sudden movement of the air or carelessness.

In order to dilute the percentage of fire-damp to the least possible amount, centrifugal fans have been used, giving a ventilating current of 150,000 up to 250,000 cubic feet of air per minute.

Fire-damp is not found in all mines, and many parts of our own country have so far been considered entirely free from it. Miners generally contend that drift openings are not liable to fire-damp, but this is not so, and with each year's more extended workings the danger increases.

Loose coal gives off gas constantly, so that the more coal is loosened from day to day the greater the danger. If the mine is allowed to stand a few days, the percentage of fire-damp decreases. There is also an increase of fire-damp with any lowering of the atmospheric pressure. In fiery mines there is a liability to sudden outbursts of gas called blowers, and against these it is hard to take precautions. Since the phenomena of natural gas have been studied these outbursts seem less strange, though perhaps no better understood. It is interesting in this connection to note the experience of the Prussian fire-damp commissioners, that the mine gas proves most abundant when the coal is folded on an anticlinal axis not reaching the surface and accompanied by a porous sandstone overlaid by clay slate. This is especially true where the drainage has removed the water and increased the porosity of the sandstone.

The influence of coal dust in colliery explosions was first noticed

investigation to one section of the Prussian fire-damp commission, which first met in June, 1881, and made its final report in November, 1885. The experiments were made in a gallery of elliptical form, 5 feet 7 inches by 3 feet 11 inches, and 167 feet long, so arranged as to give a chance for observation without danger to life or limb. The speaker gave a detailed example of the manner of conducting these experiments, and the results of a number of the experiments.

Over four hundred such experiments were carried out with the greatest care, and the results were well established.

The most important deductions are as follows: —

First: That with certain classes of coal dust an actual explosion, extending beyond the limit of the dust deposit, may be caused by a blown-out shot, even when fire-damp is entirely absent.

Second: That while the finest dust is usually the most dangerous, the chemical composition of the coal is more important, and that a volatile percentage of from sixteen to twenty-four is the most dangerous.

Third: That a three per cent gas mixture, in the *absence* of scattered dust, causes *no danger* in case of a blown-out shot, even though tamped with the most dangerous dust, and that a six per cent mixture is required for actual *explosion.*

Fourth: That dust in pure air cannot spread a flame from a lamp alone; that fire-damp up to three and three-quarters per cent, without dust, only lengthens a lamp flame; that at four per cent the flame begins to slowly spread, at the rate of one foot per second, and that at six per cent the speed is six feet per second, and incipient explosions take place. Let dust be present, and explosions may be started by an open lamp with only five per cent of gas.

Fifth: That for insuring safety, the dust must be wet down with fifty per cent of its weight of water,— not simply moistened,— and that this must be done for a space of fifty feet back from the face of the coal.

Sixth: That the Davy lamp as a test for gas is only to be trusted from three per cent up; but that the Pieler lamp can be relied on for detecting one-half per cent of gas, and for estimating mixtures of from one to three per cent.

Seventh: That the time required for the full, natural diffusion of fire-damp in a mine gallery of ordinary size is from three to four hours.

After referring to the criticisms of Prof. Sidgwick, the speaker proceeded to explain his theory of the source of business profits.

Prest. WALKER said: It is not to be disputed that, if this theory be a correct one, it supplies just what was lacking, and yields, in conjunction with well-approved theories of rent, interest, and wages, a complete and consistent body of doctrine regarding the distribution of wealth. It is not to be disputed that we have, in this view of business profits, the key-stone to bind together the other members of the arch in a symmetrical whole, spanning the entire field of distribution. But it is competent to anyone to dispute the correctness of this theory regarding the employer's proper share of the produce, and time has not yet been given for such a discussion of the doctrine as shall decide whether it is to be approved or rejected by the body of economists. The first stages of the discussion have certainly not been more unfavorable towards the view presented than was reasonably to be anticipated.

We shall best approach our present subject by inquiring what would be the share of the produce going to the employer, as such, irrespective of the proper interest on capital (of which the employer himself may or may not be the owner), in case the body of employers constituted a distinct class, either naturally or artificially defined, all of whose members were equal among themselves in the point of business abilities and business opportunities. Let our hypothesis be clearly understood. We assume, first, that there is in a given community a number of employers, more or fewer, who alone are, by law or by custom, permitted to do the business of that community in banking, in manufacturing, in trade, in transportation, or else who are so exceptionally gifted and endowed by nature for performing this industrial function that no one not of that class would aspire thereto or would be conceded any credit or patronage should he so aspire. Secondly, we assume that neither in point of ability nor of opportunity has any one member of this class an advantage as against another, each being the precise economic equivalent of every other,—all being, we might say, exact copies of the type taken, whether that should involve a very high or a comparatively low order of industrial power.

Now, in the case assumed, what would be true of business profits, the remuneration of the employing class? I answer that, if the members of this class were few, they might conceivably effect a combina-

tions, and even work absolutely indispensable to the life and health of others, compensated at rates far lower than those paid for some mere knack or skill, or physical adaptation to the rendering of a service demanded only by a whim or fancy of the consumer, which may even be positively deleterious to health or character. It is all a question of supply and demand; and, in the case assumed, the remuneration of the employing class, whatever their moral or intellectual qualifications, as compared with those of the rest of the community, would infallibly be reduced through the normal effect of competition to a level with the remuneration of the laboring class. It would then become a matter of economic indifference whether any man served the community as laborer or as employer. In this event, profits would become *nil;* that is, there would be no profits as distinguished from or preferred to wages.

Leaving now our imaginary society and returning to the actual world of industry, do we find anything corresponding to the result we have last reached? Do we find employers of labor earning profits which are no greater than the wages of labor? I answer that in every large community there are many such employers; and in every branch of business in a large community there are some such employers,—men who, by their conduct of the industrial enterprises of which they have come, no matter how, into control, realize no remuneration greater than that received by the laboring class.

Indeed, we may take a step beyond, and say that in every large community there are many employers, and in every branch of business some employers, whose conduct of business results only in loss. What with the initial investment of the employer's own inherited or previously accumulated means; what with the loan of funds by friends or relatives; what with the discount of commercial paper, under more or less of uncertainty as to the financial standing of drawers or indorsers; what with credit given by dealers for materials or supplies, and in a less degree by laborers for their work rendered,— it happens not infrequently that men carry on large business, not only with no resulting profit, but an actual loss to themselves or to others.

Just above the grade of employers we have described are found many employers in every large community, and some in every branch of business, who realize, at best, but very moderate profits. Even at the end of a long career, these men are found to have accumulated

plant? I answer: This surplus, in the case of any employer, represents that which he is able to produce over and above what an employer of the lowest industrial grade can produce with equal amounts of labor and capital. In other words, this surplus is of his own creation, produced wholly by that business ability which raises him above and distinguishes him from the employers of what may be called the no-profits class.

This excess of produce has not, speaking broadly, been generated by any greater strain upon the nervous or muscular power. Indeed, it may as a rule be confidently stated that, in works controlled by men who have a high power of administration and a marked degree of executive ability, where everything goes smoothly and swiftly forward to its end, where emergencies are long foreseen, and unfavorable contingencies are carefully guarded against, where no steps have to be retraced, and where nothing ever comes out wrong end foremost, there is much less of nervous and muscular wear and tear than in works under inferior management. The excess of produce which we are contemplating comes from directing force to its proper object by the simplest and shortest ways; from saving all unnecessary waste of materials and machinery; from boldly incurring the expense — the often large expense — of improved processes and appliances, while closely scrutinizing outgo and practising a thousand petty economies in unessential matters; from meeting the demands of the market most aptly and instantly; and, lastly, from exercising a sound judgment as to the time of sale and the terms of payment. It is on account of the wide range among the employers of labor, in the matter of ability to meet these exacting conditions of business success, that we have the phenomenon in every community and in every trade, in whatever state of the market, of some employers realizing no profits at all, while others are making fair profits; others, again, large profits; others, still, colossal profits. Side by side, in the same business, with equal command of capital, with equal opportunities, one man is gradually sinking a fortune, while another is doubling or trebling his accumulations.

Assuming, for the present, the correctness of this view of the origin of profits, let us proceed to inquire how the employer's remuneration, thus determined, stands related, first, to the price of produce, and, secondly, to the wages of labor.

could produce, with a given application of labor and capital, over and above what would be produced by employers of the lowest industrial, or no-profits, grade, making use of the same amounts of labor and capital, just as rent measures the surplus of the produce of the better lands over and above what would be produced by the same application of labor and capital to the least productive lands which contribute to the supply of the market, lands which themselves bear no rent.

If the view here presented be a correct one, it will appear that it is for the interest of the community, particularly of the wages class, that the conduct of industrial enterprises should be restricted to men of distinct, decided business ability. As, in rent, any lowering of the margin of cultivation, bringing into use lands of a smaller net productiveness, increases the cost of production of that last necessary portion of the supply which fixes the price of the whole crop, and does thereby enhance the proportion of the produce which goes to the land-holding class as rent, so in profits, we see that to commit the conduct of business to an inferior order of men, having, so to speak, smaller net productiveness in the use of labor and capital, is to enhance the cost of that last necessary portion of the supply which determines the price of the whole stock, and is thus to increase the share of the product of industry going to the employers of higher grades, as profits.

If this be correct, we see how mistaken is that opinion too often entertained by the wages class, which regards the successful employers of labor — men who realize large fortunes in manufactures or trade — as having in some way injured or robbed them, while extending to the less successful or altogether unsuccessful employers of labor a considerable degree of sympathy. So far as such sympathy springs from a natural kindness of feeling and a disposition to take the part of the unfortunate, it is right and commendable. So far, however, as it is of an economic origin, growing out of the belief that the employers of the higher class have made their large profits at the expense of their laborers, it is both mistaken and mischievous. The men who do business at the cost of the working classes are the men who do business poorly; first, for the reason that we have stated,—namely, that it is the lowest grade of business ability that determines the price of the produce; and, secondly, because incompetence in the conduct of business enterprises has much to do with bringing about those shocks to

Here, again, we see an occasion for labor to win a larger share of the produce without any injury to industry, and, indeed, directly through an improvement in the average quality of the industrial enterprises of the community. Here, again, we find an illustration of the principle that the economic condition of the laboring class is very largely put into their own hands, to deal with as they shall please, or rather as they shall will to do.

Such, in rude outline, is my view of business profits. We have here a theoretical determination and delimitation of the remuneration of the employing class, which is perfectly self-consistent and rational, and which, if approved by economic opinion as properly and fully accounting for the industrial facts with reference to which our hypothesis was constructed, gives us all that was lacking towards the theoretical determination of wages.

First: Rent is to be deducted from the produce of industry, its amount to be determined by the Ricardian formula, with more or less of remission, in fact, from landlord to tenant, under the influence of custom or kindly feeling, as these causes may be found to operate.

Secondly: Interest is to be deducted as the remuneration for the use of capital, its amount being determined by the relation of supply and demand, but always tending, through the operation of a natural law on which all economists, from Adam Smith down, have delighted to dwell, towards a minimum,— the minimum, in the case of interest, being that rate which will induce the possessors of wealth to refrain from consuming it for the immediate gratification of their tastes and appetites, and to save and store it up to the extent of making good the waste and wear of the existing stock of capital and of answering the demands for the enlargement of that stock to meet new occasions for productive expenditure. This condition may imply, in one state of society, an interest rate of eight per cent; in another, of five; in another, of three. But, whenever the rate is eight per cent, it continually tends to become five; and, whenever it is five, it continually tends to become three, inasmuch as the occasions for an increased expenditure of wealth for productive uses are certain to be soon transcended, at any given rate of interest, by the rapid accumulations of capital, which go forward by geometrical progression.

Thirdly: There is to be deducted profits, the remuneration of the employing class, determined as we have seen, by principles closely

of interest; *dx* the portion of the produce paid in wages; and, by consequence, *cd* the part retained by the employing class as profits. Let it now be supposed that an instantaneous improvement takes place in the industrial quality of the laboring class, by which they become so much more careful and painstaking, more adroit and alert, more observant and dexterous, as to effect a saving in the materials used in each and every stage of production, with a resulting increase of ten per cent in the finished product over what had been accomplished by more wasteful, clumsy, heedless operatives. This assumption is certainly not an unreasonable one, as regards the extent of the possible saving to be effected through even a slight improvement in the industrial quality of a laboring population. The total product will then be represented by the line *ay*.

Our question is: To whom will go that portion of the produce which is represented by the dotted line *xy*, under the normal operation of economic forces?

I answer: If our analysis of the source of business profits is correct, this will go to the laboring class in enhanced wages.

Let us see. To whom else should it go? To the landlord class in higher rents? No, clearly not, since the materials employed in production have not been increased, but the gain to production results from a better economy of materials, in kind and amount as before. Hence, no greater demand is made upon the productiveness of the soil; hence, cultivation is not driven down to inferior soils; hence, rents cannot be enhanced, rent representing only and always the excess of produce on the better soils above that of the soils of the lowest net productiveness under cultivation. The line *ab*, therefore, remains unchanged.

Shall the line *bc* show any change? Shall all or any part of the gain *xy* go to the capitalist class as interest? Again, no. An improvement in the industrial quality of the laboring class does not necessarily increase the amount of tools and supplies required in production. On the contrary, neat, intelligent, careful, workmen require even fewer tools than ignorant, slovenly, heedless workmen, to perform the same kind and amount of work, since in the case of the former there will be a smaller proportion at any time broken or dulled or from any cause awaiting repair. Since, then, there is no greater demand for capital in the case supposed there can be no increase in

the produce? The increase would no longer go entire to re-enforce wages. A larger amount of materials being used, a greater demand would be made thereby upon the productive powers of the soil; the lower limit of cultivation would be pushed downwards, a longer or shorter distance, to supply the increased demand; and rent would be enhanced, as in all prosperous and progressive countries it certainly tends to be. But can anyone believe that all the increase in the total product would go to increase rent, or even that rent would be increased more than in the proportion of the increase in the total product? If not, then, the portions reserved as interest and profits remaining unchanged, the share of the laboring class must be increased.

But suppose, again, that the improvement in the industrial quality of the laboring class is carried to such a degree as to qualify them to use a higher order of tools, more complicated, more delicate, and hence more expensive, than before. Here we should have an increased demand for capital; and, by consequence, supply remaining for the time the same, interest would be increased. But can anyone believe that the capitalist class would receive all, or even for any long period the greater part, or, in permanency, even any considerable part of the resulting gain to production? On the contrary, it seems to me too clear to require formal argument that the main advantage of such an improvement in the industrial quality of the laboring class will be at once appropriated by that class in higher wages; and that, in the course of time, the whole of that advantage must be so appropriated, the rate of interest tending, as we know, strongly and swiftly to decline.

In the foregoing illustration we see the importance of the economic attitude which, if our analysis has been correctly made, the laboring class occupy, as the residual claimants upon the product of industry. It is not for a moment to be supposed that the theory of business profits here presented accounts for all the facts of the case; that the principles adduced govern the remuneration of the employing class without extensive qualification. I only present this as affording a theoretical determination of this share of the product of industry, upon the assumption of perfect industrial competition. I have mentioned some of the causes which prevent profits from being kept down to the limits within which such competition would hold them. The discussion of these and other causes operating to the same end might profitably be extended.

their drivers there must be a good track in order for them to reach their highest duty and usefulness.

The best tracks of today are the result of the study and experience of nearly half a century's work; nor have we reached the summit of perfection; but improvements are being constantly made. Thousands of active minds have been and are engaged upon important problems, the solution of which adds to the vast sum of practical knowledge.

Railway officials are now looking into matters for the purpose of saving small fractions of a per cent in some of their operations, many of which are of such magnitude that a small per cent of saving amounts to vast sums.

It is not strange, but rather to be expected, that there should be differences of opinion as to the best methods of construction, etc., owing to different local conditions.

Take the railways leading out of this city, and in the matter of joining the rails it is quite correct to say that each has a special plan.

In weight of rails, all are now laying those of 72 pounds per yard, yet each road has a different section, a slight modification in form and distribution of the metal, hoping thereby to reduce the cost of operation and maintenance. Briefly, these differences indicate, in some measure, the efforts on the part of officials to obviate some forms of wear, which experience shows takes place on their lines. It is but the constant repetition of practically testing ideas to keep pace with the needs of traffic and consequent wear, which has taken place ever since rails were used.

The first rails were of cast iron; these were replaced by the strap rails, which were from one-half to five-eighths of an inch thick, and two inches wide, spiked to a longitudinal stringer, and were considered, at that time, heavy rails. Previous to 1831, Colonel John Stevens invented our present form of rails.

All of the first rails used in this country were rolled abroad, and were very expensive. In most cases the quality of the material was excellent, but their cost led to the adoption of very light sections. The joints were and still continue to be a source of great trouble; they would go down, causing an unpleasant jar as the cars passed over them.

To obviate this, various joints were introduced and tried; also

surface of the track than was possible with iron rails, that heavier locomotives and cars were built to accommodate the increasing traffic. When these were put into service they increased the deflections of the rail, which eventually acquired permanent set at the joints, increasing with the length of service.

Studying the forms of permanent set of the rails upon a number of roads a few years since, I found they could be mostly referred to three primary forms.

1st. Those low at the joints and high in the center as it appeared to the eye in the track. This is the most common form.

2nd. Those low at the joints and also at the center.

3rd. Those which had a considerable number of undulations throughout their entire length. This form was quite common in some brands after the change was made from the light to the heavy, or deep-headed rail.

They gave a tremor to the cars which caused the riding to be unpleasant to the passengers.

The trackmen were unable to overcome this feature, and no matter how well they maintained the joints, the track did not ride smoothly, nor could it be long kept in surface.

Each mill gives a slight difference to the finish of its rails, which is often sufficient to enable me to tell from the original diagrams, made by my apparatus, the brand of the rails over which I am passing if they have not been laid over two years. Some of the mills gave the subject immediate attention, and the rails have been much better of late, and can be further improved by better methods of straightening. Another form of rails which I have found in the tracks the past three seasons is the reverse of the first form mentioned above, high at the joints and low in the center.

With angle plates this rarely occurs, except in tracks nearly in their best condition; the rails appear to the eye nearly in surface, the centers only deflecting under the passing train.

When these deflections do not exceed a central depression of one-eighth of an inch in eleven feet, they are hardly noticeable in a passenger coach; but when they are more, or that amount in shorter distances, they are perceptible.

The development of the forms of permanent set in the track is one of great interest, and has quite definite relations to the section of

The benefits to a road in raising the standard of track are, besides the saving of the rails, a reduction of the friction of trains, consumption of fuel, car repairs, and other operating expenses. The difference to a trunk line in the cost of transportation over a track where the average deflection per joint was 5-16 of an inch, and over another track where the average deflection was only 3-16 of an inch, represents such vast sums that those who have not investigated it can hardly credit the amounts. The data for such calculations I have obtained from my diagrams of different roads, and the figures agree as closely as could be expected. A reduction of $\frac{1}{8}$ of an inch from the 5-16 of an inch deflection shows a saving of from 1.4 to 1.5 mills per ton mile. The first 1-16 of an inch saved about 0.8 of a mill, and the next 1-16 of an inch saved about 0.6 of a mill per ton mile.

One of the trunk lines' tonnage for 1875 was 2,100,000,000 ton miles, and this business was done at a cost of over 1.5 mills per ton mile more than what it cost two other trunk lines to do their business on much better tracks the same year. The extra cost of 1.5 mills per ton mile on their business represents $3,150,000. This means that a large portion of that sum could be expended over and above the usual yearly allowance for improvements in the track, and if properly applied, would be saved in the current expenses of operating. In making such a statement public I am not only relating what ought to be, but what has already been, accomplished by some roads, and others have good precedents to follow.

These actual facts only confirm what our ablest railway officials have long maintained,— that one of the first requisites in the reduction of expenses is a good track. With that other desirable improvements follow.

The average cost of transportation per ton mile on the best tracks today is about 4 mills; the average rate received is from 5½ to 6 mills. So far as I can obtain figures no country shows such a low rate of cost of transportation, or are the charges as low as they have been here on the trunk lines.

To give a tangible idea of the cost and system of transportation, the charge on a barrel of flour from Chicago to Boston has been less than its cartage would be for three miles in your city. Such practical facts are in one sense the measure of the remarkable progress and improvement in railway tracks and appurtenances the past few years.

a uniform loss of metal over the surface, but it comes out in small particles, leaving an irregular surface. The better physically the quality of the steel the smaller are the particles, and the smoother the surface, and the longer the steel wears.

Under the wheels of the cars and drivers of the locomotives, the pressure per square inch of the surfaces in contact in most cases exceeds the elastic limit of the steel, measured by the usual method of tension. The limit rises on the surface of the rails and tires, but is still insufficient to prevent rapid flow and loss of the small irregular surfaces in contact.

The slow rate of wear of the light-headed rails under the then existing wheel tonnage was studied, and deeper heads given to subsequent rails, for supposed increased service. Experience now shows that rails do not wear down in a smooth, uniform manner, but, on the contrary, the wear is very uneven per length of rail, and they are removed from the track on that account before they are fully worn out.

What is needed today for present, and to anticipate the average, increase of wheel tonnage is to widen the head of the rail, thus increasing the surface of contact, in order to distribute the weight over larger areas, and thereby check the rapid loss of metal.

To check the deflections, stiffer sections of rails are needed, or in other words, the material must be distributed so as not only to decrease the rate of wear, but make a stronger rail. The problem is not wholly one of weight of rails, but also of form.

The heaviest rail in use now is eighty pounds to the yard. The section as used by the New York Central & Hudson River Railroad is five inches high and nearly the same width of base, the head is $2\frac{3}{4}$ inches wide but comparatively shallow. The upper corners of the head are 5-16 of an inch radius, while that of the top is 12 inches, giving a broad bearing surface for the wheels, thereby checking the rapid increase of wear. The increased wear of the treads of all the wheels is of far more importance than the small percentage of wheels condemned for sharp flanges.

The 72-pound rail which has been in use on the Boston & Albany Railroad since 1880 has been brought to such good surface in the track that only from five to eight deflections in length of 11 feet under the weight of a 34-ton car exceeded one-eighth of an inch per mile.

The speaker closed with a [illegible] of his "Dynagraph and [illegible] Car." By means of this car an accurate record of the [illegible] at the time the car passes over it is made [illegible] under the head of the rail at every point where the deflection [illegible] is more than a certain amount, which [illegible] the section men the exact [illegible]. The first time a car is run over a [illegible] where the deflection is more than [illegible] but on subsequent trips this is reduced sometimes [illegible] and in one case to three thirty-[illegible]. This is about as close as it is possible for the section men to keep the track.

[illegible] from the car, taken from several roads, were [illegible].

A large number of [illegible] views were projected on the screen to illustrate [illegible] of the subject.

The meeting closed with a vote of thanks to the speaker for his very [illegible] and [illegible] paper.

MEETING 362.

[illegible] *Automatic Fire Alarm.*

[illegible] AND [illegible]

[illegible] meeting of the Society of Arts was held [illegible] Mr. C. J. H. [illegible]

[illegible] meeting, and [illegible] Committee presented [illegible] of the ensuing year.

[illegible] Committee was read and ordered [illegible]

The Permanent Meteorological Committee then reported through its chairman, Prof. W. H. Niles.

REPORT OF THE METEOROLOGICAL COMMITTEE.

Prof. NILES said that the duties of the committee during the year had been unusually few. The Signal Station in Boston had been inspected by the members, both collectively and individually. It was found to be well kept, the instruments appeared to be in good condition, but the sergeants had not at all times been aided by competent assistants.

By the failure of Congress to make the requisite appropriations, the Signal Service had been forced to suspend some of the most important functions of the Weather Bureau. The Service had not been able to transmit by telegraph the reports of the weather at various important points, hence the issuing, at Boston, of a daily weather map had been rendered impossible for a time. Such interruptions seriously reduce the value of the Signal Service to the country. It is much to be desired that the Weather Bureau should receive that financial support which shall enable it to prosecute its work effectively and continuously.

The published "Indications" of the weather had received during the year more adverse criticism than usual. In many instances the criticisms did not accord with the facts, but there have been good reasons for the belief that, in a broad country like our own, weather warnings can be made more accurate, and therefore more valuable, than ours have been during the past year. If there is not an improvement in the "Indications," it may be well for the members of the Society to express their united request that a weather service should be so sustained by stated and adequate appropriations that the best efforts of the most competent men may be continuously employed in work which shall yield the greatest benefit to commerce, agriculture, and other industries.

THE MARTIN-WILSON AUTOMATIC FIRE ALARM.

The chairman then introduced Mr. A. H. Kendall, who read a paper descriptive of the "Principles of the Martin-Wilson Automatic Fire Alarm."

the head of the bureau of building inspection, once uttered a great truth in saying that a great fire was a neglected small one.

I purpose submitting some facts relative to thermostats in general, and their application to the Martin-Wilson automatic fire alarm system in particular, with a comparison of the different systems of application. It is useless at this late day, when the losses by fire in the United States are so heavy that fire insurance has almost ceased to be a profitable business, to go into the question of the value of an automatic fire alarm. Any invention or application that is absolutely certain to automatically indicate the location of a fire in a building in its incipiency before it has had time to do much damage, and when it can be easily extinguished, deserves the earnest attention of insurance companies, property owners, capitalists, and the general public.

The foundation of an automatic fire alarm is the heat detector, and this company claim that their heat detectors or thermostats are at once the most scientific, the simplest, and the most reliable instruments yet invented; and that their system of electrical circuits and apparatus used in connection therewith, for the purpose of sounding a fire alarm by the heat of the fire itself, cannot be excelled. The idea of utilizing electricity to give notice of undue heat is by no means a new one. But the great difficulty has hitherto been in its execution, from the fact that a fire being of comparatively infrequent occurrence, the circuits, by reason of an accidental break, earth connection, or a weak battery, would be apt to be in an inoperative condition when a fire occurred, and so fail to do the work expected of them. In 1830, Dr. Ure, the celebrated English chemist, invented a thermometer in which the movement of a spring composed of two unequally expansible substances, for instance brass and steel, indicated the temperature to which it was exposed. This instrument he called a thermostat, and he utilized its motion to regulate the valves or dampers of furnaces, and since that time thermostats and thermometers embodying the same principle have been devised by different inventors, a familiar example being the common metallic thermometer. From 1830 to 1881 numerous thermostatic heat detectors were invented, based on various principles, such as the expansion of metals and air, beeswax, and similar substances, and the rending or rupturing of fragile vessels by the vaporization of volatile liquids, such as alcohol, ether, etc.

way interferes with its perfect working at once sounds its own alarm. So you will at once perceive that, other things being equal, the closed circuit is, without question, far superior to the open, inasmuch as in one we hope for the warning, in thè other a failure to receive it is an electrical impossibility. What has heretofore prevented the general use of the closed circuit has been, first, the much greater expense, and, second, the supposed impossibility of making the different alarms intelligible and distinct in themselves.

After a long series of experiments with thermostats variously constructed, embodying the foregoing principles of operation, the Martin-Wilson Automatic Fire Alarm Company have finally adopted two, one an open and the other a closed circuit instrument, which are simple and effective as practical heat detectors. In both forms, the tank or reservoir is held firmly suspended in a dish-shaped frame, with its rigid face downward and its flexible face upward. The latter, coöperating with the circuit controlling parts, which are attached to the rim of the frame, is slotted to freely admit the surrounding air to the surface of the tank, and also to protect it from accidental blows, while, to exclude dust or dirt from the working parts, a cap or cover is closely fitted over the rim of the frame, great sensitiveness and little liability to injury or derangement being thus secured. It will readily be seen from this description that, while the contact points operated by the movement of the upper surface of the tank are protected from dirt or dust by the cap or cover, the under surface is directly exposed to the air, which easily passes through the slots in the supporting and protecting frame, and that any change in the temperature is very quickly communicated to the contained liquid. Hence the instrument is extremely sensitive, and at the same time is perfectly protected from injury or derangement of any kind, a combination of results hitherto unattainable.

Delicate and consequently uncertain adjustments of contact points to vary the operative temperature, a feature so objectionable in most thermostats, are eliminated from this instrument, as each reservoir operates at a certain definite temperature dependent on the character of the liquid contained therein, and as the reservoirs can be readily taken out of or inserted in the supporting frame, the temperature at which it is desired any instrument shall operate is readily controlled.

The two kinds of thermostats most used at the present time are

the cause and location of the difficulty, but it also signals without giving a fire alarm anything tending to any interference whatever with the full operation of the system, such as any break, derangement of the system or weakening of the batteries before they become inoperative, whether it be caused by neglect, accident, or design; in short, a fire produces a fire alarm, and any fault in the system makes an inspector's alarm. Each class of signals is of separate and distinct nature, and never to be confused, as they are both visual and audible. We submit that no electrical apparatus contains such a wide range of operation, all of them of the highest practical value, and possessed by no other automatic alarm. And these results are not accomplished by any complex mechanism, but each function of the system is operated by devices simple in themselves, and all tributary to the desired result of obtaining a guaranteed safety under all circumstances. An automatic fire alarm with open circuit is dead until a fire is presumed to scorch it into life. Its complete arrangement can never be assured in any other manner. A broken wire, faulty connection, or weakened battery, or some obstruction, may exist without knowledge on the part of anybody, and if so, when the circuit is called on for action, it will fail to respond, thereby rendering the whole plant completely inoperative. It only remains to say that a closed circuit is acknowledged by all to be the best in all cases where it is essential to give a warning when a conducting wire is broken. But up to the present time the extended use of such a circuit has been deemed impracticable in automatic fire alarms, on account of the accidental breaking of the circuit giving an alarm identical with that given by the heat detector or thermostat, the only other objection heretofore having been the increased cost of maintaining the batteries, owing to the forcible and constant current passing through them. This has been the riddle that electricians have been trying to solve for years, and the best evidence of its solution by arrangements peculiar to this system for economizing the amount of battery power constantly used is that we are able to compete with any system on a basis of dollars and cents. Of its superiority there can be no question.

At the close of Mr. Kendall's paper the chairman introduced Mr. M. Martin, who gave a successful exhibition of the working of the apparatus, showing clearly that a broken wire, a ground, weak

any required intervals of time. As the jet of steam enters the cold water that occupies the space between the two points of observation it is condensed,— a vacuum is formed, and a loud cracking or snapping sound is produced.

The description thus far relates to the sending apparatus;— the receiving part consists of a drum, or tympanum, provided with a socket in which a wooden rod, or a metal tube, a wire or other good conductor of sound is inserted. This rod or tube leads from the tympanum to the ear of an observer on the vessel or steamer that is to receive the signal or message from the other steamer. The drum is made of sheet metal, that is sonorous, and may be about one foot in diameter and an inch in thickness. Air is enclosed in the drum, which is submerged by an attached weight to the depth of a few feet below the surface of the water. It is not necessary that the drum should be on the same level as the lower end of the steam pipe, as the sound and vibration proceeds in all directions.

In the case of two steamboats nearing each other in a fog, both being provided with the apparatus for sending and receiving signals, the sounds may be often repeated, to call attention. If the course of a distant boat is wanted, a message may be sent by the use of the telegraphic alphabet.

The velocity of sound in water is about four thousand seven hundred and eight feet per second, equal to about nine-tenths of a mile, therefore, for all practical purposes in its use for signals, its transmission for several miles may be considered as instantaneous.

When vessels are near each other the loud cracking sound of the steam, as it escapes in the water, may be heard by using a small tube of metal, open at both ends, or a wooden rod, as receivers of sound; in this case the tube or rod should enter the water about two fathoms in order to present sufficient surface to the action of the sound waves, the other end of the tube or rod being held to the ear of the observer.

This system of signals is suitable for giving to passing vessels notice of the proximity of dangerous capes, headlands, or shores, special provision being made at these points for generating steam to be applied as herein stated; it can also be used between terminal stations, or positions that are not in the line of direct vision.

The stop-cock in the pipe may be placed near the steam generator, and a rubber hose used for the conveyance of steam to the open

ment has followed in such rapid succession that our sense of satisfaction at having placed within our reach one of the most valuable acquisitions to modern civilization is only equaled by that produced by its rapid growth and its many opportunities for application.

We all no doubt recognize that the year 1878 will ever be memorable in the history of electric lighting, for the reason that the first real practical developments took place in that year; and, although the efforts of that time may seem to sink into insignificance by the side of the perfected work that we may now see around us on every hand, yet in that year the proper direction in which to work was truly outlined and indicated, and a line of action pointed out which was subsequently followed up by the two gentlemen referred to with a persistence and ingenuity that must ever elicit our admiration and respect.

However, as time rolled on, and the magnitude of the work began to assume considerable proportions, it was found that the arc system of lighting outstripped the low tension incandescent system, principally because the problems involved in the respective systems were very much simpler in the one case than in the other. In the latter case the necessity of having to deal with very heavy currents, and the equal distribution of these currents throughout the system, required all the ability that the practical electrical engineer could bring to bear upon the work to be done to do it in such a manner as to keep that work within the limits of a profitable commercial undertaking; and how ably and well that work has been done is evidenced by the successful and gigantic undertakings that are being continually carried out.

Notwithstanding these successful undertakings on the part of the low tension incandescent advocates the time has now arrived when, in consequence of the enormously increased magnitude of the demands of the public for a more general extension of incandescent lighting, we find a necessity imposed upon us, in order to meet those demands, of making some radical departure from the lines in which we have hitherto been working, or, on the other hand, neglect the public's requirements, and confine our operations within certain narrow limits.

The object of my remarks this evening will be to endeavor to show the advantages of the use of a system of electrical distribution by means of induction coils, and how nearly such a system fulfills the necessary practical, economical, and commercial conditions imposed upon it.

minals of the lamps should be maintained constant, or nearly so, no matter how much the load upon the coil might vary. It was an easy matter to calculate the loss in the copper, knowing the resistance and the current to be carried, but it was not so easy to determine the number of convolutions, and the quantity of iron necessary. It was found by experiment that many of the rules which guide the best manufacturers in the construction of dynamo machines could be applied in the construction of these induction coils,— that is, the loss in the copper wire must be as little as possible, for obvious reasons, and that, as in the case of the field of the dynamo, you must keep well below the saturation of the core, and the magnetic circuit must be as short as possible. Should you depart from these rules a lack of regulation or efficiency will follow.

I may say just here that the courteous manager of the Boston Electric-Light Company has been good enough to give us current this evening from the Company's city circuit; and for the first time in this branch of lighting we are able to give a practical experiment from a practically operating commercial plant.

[The speaker here exhibited a coil in which the core was oversaturated when working at full load. On this coil there were 25 16-candle power lamps, each being 50 volts, and taking one ampere each. The units of the coil and of the circuit in which it is working are — at the poles of the dynamo 1080 volts, at the poles of the primary of this coil 1050 volts, the current in the primary with the 25 lamps on is 1.25 amperes. There are 50 volts at the poles of the secondary, and 25 amperes in the circuit. The resistance of the primary circuit is 16 ohms, the resistance of the secondary .059 ohm. We find therefore that there is a loss of three per cent in the main line, and five per cent in the induction coil. This is equal to a loss in the system of eight per cent, — not an excessive one by any means. It was noticed by the effect on the lamps that the regulation of this coil was poor.]

The law of self-inductive resistance (or, as it is sometimes called, counter electro-motive force) is a most beautiful and accommodating one; for instance, in this coil in the primary circuit we have an electrical resistance of some 16 ohms, and as the pressure at the terminals of that circuit is 1050 volts we should be taking not 1.25 amperes, but some 65 amperes, if it were not for this something which

This development of counter electro-motive force, or self-inductive resistance, is just the condition of things that should and does prevail in these coils that we have here tonight, so that, if we now call this a 20-lamp coil, when we turn out all the lamps but one, there should be a resistance of some 21,000 ohms, plus the small electrical resistance of the wire. The evidence of that is this: one lamp in the secondary circuit of this coil takes only one ampere, therefore, there being nothing else in the secondary circuit of the coil, there should (and by the construction of the coil there can) be only 1-20 of an ampere in the primary circuit. Now we have shown that on the proper full load (20 lamps) only one ampere is required in the primary current, and consequently with double the resistance (10 lamps) in the secondary only one-half an ampere would be required (at constant pressure, be it remembered) in the primary, and, therefore (the neutralizing current in the secondary being reduced by one-half), there would be double the self-inductive resistance in the primary, 2000 ohms, and so on until with the same pressure there will be 1-20 of the current, and thus we have twenty times the resistance in the primary; therefore, we get 21,000 ohms of effective resistance in the primary circuit, or 1050 volts $\div$ 21,000 ohms $=$ 1-20 ampere.

We were speaking a short time ago of this particular 20-lamp coil not being good in the sense of regulation with the extra load put upon it, because we too nearly approached the magnetic saturation point of the core. Magnetic circuits are like electrical circuits in some respects; if you overload a wire, you will have a certain loss, and in the magnetic circuit the same general principle holds good.

[Mr. Slattery next showed a 12-light coil, which was constructed with due regard to the loss in the wire and other wasteful effects, and the regulation was found to be very close.]

At this point I should like to express my opinion that in actual practice there is no such thing as absolutely theoretically perfect regulation. It is well enough to talk about, but commercially speaking it is impracticable. However, the very slight variation which you may or may not have been able to notice in this 12-light coil, as between full load and one or two lamps, is, from a commercial point of view, quite good enough.

True, almost perfect regulation is only a question of putting

last machine had a difference of potential at its poles of 1060 volts, the other 1000 volts. By means of a switch, the two armatures were suddenly thrown in multiple arc. For a moment there was a slight sag of the belt of the lightly loaded armature, there being a momentary tendency on the part of the heavily loaded armature to drive the other in the opposite direction as a motor. Instantly, however, both machines fell into step, evenly dividing the load between them, both delivering at exactly the same pressure. This experiment shows us that we may allow ourselves considerable latitude in regard to speed and electro-motive force in coupling alternating dynamos in multiple arc. When switching an armature out of circuit, when two or more are running in multiple arc, it was found desirable to have a small bank of lamps in circuit with the armature you wish to cut out, in order to prevent any hurtful effects, because, at the moment of cutting out, the armature circuit would be open, and the field being fully excited there would be an infinite resistance in the circuit, the volts would, therefore, have a tendency to rise to a dangerous degree, but a bank of lamps across the poles of the machine will prevent that occurring.

A good deal has been heard within the last few months of self-exciting alternating machines, as if there were something very original and advantageous about them. As to the originality, it is decidedly problematical, and, in my opinion, the advantages, such as they are, are on the side of the separately-excited machine. There is no great difficulty in making a self-exciting alternating machine; on the other hand, without going into the whole merits of the question, which time forbids me to do on the present occasion, I will simply say that the construction of self-exciting alternate dynamos is quite familiar to any of the best continuous current dynamo manufacturers. The objections to them, or to any shunt-wound high-tension dynamo of 1000 volts or upwards, are, first, it is an expensive machine to build, and, in the event of the dynamo fusible plug for the main line giving way, when at full load, in consequence of a dead cross on the line, it will be a rare circumstance if the machine is not destroyed, because at the moment of rupture of the main the volts at the dynamo will rise enormously, and the current will discharge itself through some vulnerable point in the machine.

I find that it is necessary for me to apologize for not having en-

tered more minutely into distribution by the aid of converters. I feel and know that I have left many important points untouched; however, one of the principal objects of this paper will have been attained if I shall have succeeded in directing some increased thought towards this growing branch of electrical lighting, a branch that I believe in time will take precedence of all others, as it brings electricity in its most flexible and utilizable form, and by comparatively cheap means, within the reach of all.

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NOTICE.

The Society of Arts, established in conformity with the plan of the Massachusetts Institute of Technology, as set forth in the act of incorporation, April, 1861, held its first meeting on April 8, 1862.

The objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement in connection with arts, agriculture, manufactures, and commerce.

Regular meetings are held semi-monthly from October to May, inclusive, in the Institute building: and at each meeting communications are presented on some subjects germane to the objects of the Society, as stated above.

The present volume contains the abstracts of the communications made during the year ending October 1, 1888, most of the business portions of the records being omitted.

The thanks of the Society are due to Mr. Geo. S. Strong for the loan of the electrotypes used in illustrating his paper on the "Strong Locomotive;" to the publishers of the *Modern Light and Heat* for those illustrating Mr. Stanley's paper on "Recent Improvements in Systems of Electrical Distribution," and Prof. Anthony's paper on "A Study of Alternating Current Generators and Receivers;" and to Mr. Wm. F. Chester for that illustrating his paper on the "Johnson System of Heat Regulation."

For the opinions advanced by any of the speakers the Society assumes no responsibility.

LINUS FAUNCE,
Secretary.

Boston, June, 1888.

Erratum.— On page 108, 7th line from top, for 140 read 400.

PROCEEDINGS OF THE SOCIETY OF ARTS

FOR THE TWENTY-SIXTH YEAR.

MEETING 364.

The Arms and Armor of Ancient Japan.

BY MR. TATUI BABA.

The 364th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Oct. 13th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, the President introduced MR. TATUI BABA, of Tokio, Japan, who read a paper on "The Arms and Armor of Ancient Japan."

MR. BABA first described the difference between the Japanese and the Chinese, stating that the Japanese were warlike, while the Chinese were a commercial people; that, although they might be of the same race, yet they were very different in their sentiment, language, and art.

The Chinese language is symbolic or hieroglyphic, but the Japanese is syllabic. The Japanese alphabet comprises only forty-seven characters, while the Chinese has not less than five hundred symbols. About the third century the Chinese language was introduced to a considerable extent in Japanese literature, but it was confined wholly to the men; the women, among whom were many noted authoresses, wrote in pure Japanese.

The lecturer next spoke of the differences in the fine arts of the two nations, remarking that, while Japanese art is always the representation of Nature, Chinese art, at least in its later development, is something between drawing and writing. The Chinese, he said, used

known. The arrows are classified into four groups, according to the use to which they are intended to be put; viz., naya, or hunting arrow; soya, or arrow for the army sent out to attack; sasiya, or arrow for defence; and matoya, or arrow to shoot at a target.

The science of archery reached a high degree of cultivation in Japan, so much so that several distinct schools were formed, each claiming to possess certain secrets unknown to the others. One set of maxims, however, applied to all. These are styled the "ten disadvantages" or conditions under which an archer ought not to shoot: (1) when he is preoccupied; (2) when he is melancholy; (3) when he has been running too fast; (4) when he is intoxicated; (5) when he is hungry; (6) when he has eaten too much; (7) when he is angry; (8) when he is not inclined to shoot; (9) when he is too anxious to shoot; (10) when he is envious of some other archer's skill. The speaker then showed the different methods of handling the bow in shooting.

He next showed a Japanese spear, telling the legend of the god who, standing with a goddess on the floating bridge of heaven, dipped the point of his spear into the water. When he raised it the water from the point froze, and, dropping, formed an island.

The oldest spears now in existence, supposed to date from 672 A. D., have the head about fourteen inches long, and the handle is made of a round piece of wood about five inches in diameter, and a little more than five feet long. During the fourteenth century the spear was lengthened so that the handle was sometimes twenty feet and the head five feet long.

The halberd is not spoken of in Japanese mythology, although it is an old weapon; Japanese history mentions that the Mikado Kozinteno caused the first one to be made, in 770 A. D.

The halberd resembles the spear in possessing a long handle, but differs from it in having a long blade, slightly curved, widening gradually toward the upper end, with an edge at one side only. Its blade is sometimes three or four feet in length, and its handle six or seven feet. It is used in quite a different way from a spear. The mode of holding the latter is always to use the left hand before the right, while that of holding the former is to use the right hand before the left, so as to give facility in cutting as well as thrusting. The handle is used to thrust at the enemy, so that both ends are used

MEETING 365.

An Electrical Apparatus for the Measurement of Water.

BY MR. N. M. LOWE.

The Cosmosphere in Teaching Phenomenal Astronomy.

BY PROF. F. H. BAILEY.

The 365th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Oct. 27th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, the President introduced Mr. N. M. Lowe, who described "An Electrical Apparatus for the Measurement of Water."

Mr. LOWE said that the apparatus was designed to be used in connection with the meter tests which have been in progress for the last five or six months, and that it had served its purpose admirably, causing an undoubted saving to the city of several thousand dollars. The apparatus is arranged so that the short arm of the scale beam breaks an electric circuit when the beam is horizontal, thus releasing a weighted lever which, in falling, shuts a valve, thereby stopping the flow of water, and also stopping a clock.

To test a meter, the clock is set at 12 M., and started the same moment that the valve is open, which starts the flow of water through the meter. This water flows into a tank which is placed on a scale. The scale beam is weighted so as to swing when any definite amount of water has passed through the meter. The swinging of the scale beam, as explained, automatically shuts off the supply of water, stops the clock, and rings a bell. The observer then reads the meter and compares the amount recorded by it with the actual amount passed through as weighed by the scale.

The apparatus was shown in working order, dry sand being used in place of water.

The spectators were then asked to imagine that they were traveling over the earth from equator to north pole, and to see the variation in the daily motion caused thereby. Then, while the globe was revolving from east to west, it was also revolved through one-fourth of a revolution from north to south around an invisible axis, the poles of which occupied the east and west points of the horizon, the central plane remaining constantly horizontal, thus showing the difference in apparent daily motion as seen from different northern latitudes,—fewer and fewer stars rising and setting as the latitude increases, and those moving nearer and nearer parallel with the horizon, until at the north pole the stars are seen to move from left to right perfectly parallel with the horizon, and not a star ever rising or setting. The latter remark applying to the fixed stars; the seven wandering stars — the "great gods" of the astrologers — would then be seen to rise and set, the sun once a year, the moon once a month, and the other five in varying lengths of time.

Next, the instrument was set again for Boston, and the movements of sun and moon illustrated, as here seen. On the sun's yearly path is marked his position for each day, hence the place and time of his rising and setting and his movement through the heavens for each day are clearly shown. Some of the most puzzling moon phenomena were reproduced and explained with perfect clearness; the reason why the moon sometimes runs high and sometimes low; why the highest full moon is always the one that occurs nearest Dec. 21, and the lowest the one that comes nearest June 21; why the new moon's horns are pointed upwards, "to hold water," in the spring, and so tipped as "to spill water" in the autumn; why the harvest moon when full rises, at this latitude, only half an hour later for several successive nights, but when new an hour and a quarter later.

One of the most interesting and instructive illustrations is that of the varying phenomena of day and night for the different zones. The Professor claims that his experience with schools of all grades has convinced him that but very few pupils of any grade obtain, from the theoretical method in which the subject is taught, anything like clear conceptions of the difference in day and night in the different zones. He has even met teachers of astronomy who have maintained and taught for years such errors as that the sun would be seen,

eastern point towards the northern. Each succeeding morning for six months it comes up at six o'clock a little north of its previous point of rising, till in midwinter it rises about one-fourth way from east to south, thus using one-eighth of the horizon for rising purposes; and as it uses the same amount of the horizon for setting, it uses for both a very little more than one-fourth of the horizon. The same parts are used in reverse order during the next six months. The amount of the horizon used by the sun for rising and setting purposes increases from about one-fourth at the equator to three-eighths at Boston, five-eighths at St. Petersburg, and all of it at the arctic circle. All of it is used every alternate three months at Point Barrow, Alaska, and all of it in one month at Fort Conger, followed by five months in which the sun does not rise or set.

The illustration of the phenomenal movements of the planets were only hinted at for want of time.

The lecturer next took up the subject of the "Precession of the Equinoxes," and showed the changing position of the heavens as seen from Boston during the entire precessional period of nearly twenty-six thousand years. By setting the instrument for the latitude of the Great Pyramid, some of the statements of the "miracle in stone" school of pyramidologists can be verified and others proved false, and the fallacy of the fundamental argument of their theory exposed. Lastly, the movements of the equinoctial points and changing position of the signs relative to the constellations were illustrated and explained.

The instrument is also capable of illustrating apparent movements of sun and stars, as seen from any latitude of Venus, Mars, or Jupiter, consequently the phenomena of day and night as experienced by the inhabitants of any of our planetary neighbors.

The meeting closed with a vote of thanks to the speakers.

bonic acid contained in the carbonate of lime. Then a chemical reaction takes place. Under a high temperature, the lime rendered caustic by the expulsion of the carbonic acid and in intimate contact with the silicate of alumina, the latter is decomposed, and a new combination is formed, known as silicate of lime and alumina. If magnesia be present, then a triple silicate of lime, magnesia, and alumina is formed.

In a Portland cement each atom of silicate of alumina must come in close contact with its equivalent of lime carbonate. A failure in this regard will result in the production of a cement that will heat, check, and expand, thus showing the presence of free or caustic lime or free clay, and no amount of subsequent grinding or mixing will change these conditions.

[The speaker quoted from Henry Reid's work on Portland cement, to show that its manufacture will be attended with a danger that must ever be constant so long as the matter of mixing is entrusted to human hands.]

While Nature did not always deposit her natural cement rock formations in true combining proportions, no handicraft has ever yet excelled or even approached her in the art of mechanical combinations of clay and carbonate of lime, for with natural cements, however much the proportions of ingredients may vary, as between the upper and lower layers there is usually a large percentage of the bed that is so well proportioned as to yield a good cement when all are mixed together; and even the layers that are not well proportioned, owing to their finely commingled condition, are not as dangerous an element in the mass as is that of an equal amount of an imperfect mixture in an artificial cement. As a rule, the lower layers contain more clay than those above, the proportion of clay gradually diminishing and that of carbonate of lime increasing as we ascend in the series of layers. This variation in proportion in the several layers amounts in some deposits to twenty per cent, and so it may be seen that although the cement produced from such deposits may after a thorough mixing, first in the kiln and then in the grinding, exhibit by analysis a cement made up of very fair proportions, it also shows that it is not impossible to find that a cement may be heavily overclayed and still contain free or caustic lime; and it must be seen that although the proportions may be correct, yet the percentage of true

cates, and showed that silicates are formed during calcination, and not by the action of water afterward.]

It is an error to suppose that the natural cements of this country are all about alike, and that the testing machine will very quickly tell us whatever differences may exist. It is surprising how widely some of our natural cements may vary from the correct standard of proportions and yet sustain a high tensile strain, and be acceptable to the consumer. A well balanced cement will withstand the action of frost many years, while an overclayed one, whether natural or artificial, will not, and of this the testing machine gives no indication. If we take two cements, one being natural and the other artificial, and so nearly alike in composition that a chemist could not distinguish between them, the artificial will test higher than the natural product, but can it be truthfully maintained that it is the better of the two? If we are governed by prevailing public opinion we must admit it, for the testing machine says so. Had the chemistry of cement and the laws governing combining proportions been made more of a study in the past, we should not now see the whole question submitted to this crucial test called tensile strain.

The testing machine came into use about 1860, and the Portland cements came to be considered as better than the natural because they would stand a higher tensile strain. If the Portlands were superior, it is a little strange that such engineers as Grant, Colson, Mann, and others had not discovered it in all the years prior to 1860; although it may be urged that they were confronted with the excellent work done with natural cements, in the construction of the railway tunnels, the heavy stone arches and deep foundations done during the earlier day; there was the great Thames tunnel, commenced in 1807 and completed in 1843, every stone of which was laid in natural cement, and stands today in all its perfectness, a powerful argument in favor of natural cement. But the tensile strain fever had set in, and men argued then as now that, if one cement sustains a higher tensile strain than another, it must be better, because it is stronger. And this argument seems unanswerable, and, coupled with the fact that it is a quick and ready means by which the engineer may draw conclusions, has been the cause of its adoption to such an extent that today the engineer who does not have access to a testing machine is considered behind the times.

tested, weighing carefully every feature that gives the slightest promise of throwing light on the subject, and now, after all these years, we are compelled to admit that we have not been able to discover the slightest relationship between high test and good quality. Practical experience teaches that we can find both good and bad cements that will test high, and good and bad cements that will test low. A cement may be so overclayed that in a barrel of 300 pounds there may be but 225 pounds of silicates or active setting matter, yet I have seen such cements test as high as 100 pounds in twenty-four hours. Such cements, when slightly underburned, behave very well in air or water, the free clay acting as a pozzuolana; excessive heat, however, greatly impairs or destroys the silicates, and if carried to a high point the resultant cement becomes inert. With our present modes of burning there will be variations beyond the control of the burner, caused by changes in the direction and velocity of the wind. Yet such changes have but little effect on cements containing an excess of lime (not exceeding five per cent). Such cements will sustain a high temperature in the kiln and be benefited thereby. If it becomes a question to decide which cement to choose, one containing an excess of clay or lime, we must unhesitatingly choose the latter. This is contrary to the prevailing belief; yet, if we accept the teachings of time, it must be conceded. The overclayed brands are at their best when fresh, while those containing an excess of lime require age to allow a thorough hydration of the free lime by exposure to bring out their best qualities. They will withstand the action of water equally as well as the overclayed brands, and for all masonry above water, or where subjected to water and air alternately, are infinitely superior. If properly hydrated, such cements will sustain immediate immersion even better than the overclayed brands, and will test equally as high; yet the fracture will show that crystallization has hardly set in at twenty-four hours, as they will yield readily to the knife, while the overclayed varieties show a much harder set, thus disproving the idea so prevalent that overlimed cements set quicker than the others. The setting of a cement becomes slower as the proportion of lime is increased, until we pass up through the slow-setting hydraulic limes and arrive at the pure limes where crystallization ceases. We must remember that that which causes a cement to set promptly under water is also the cause

have consumed upwards of seventy-five million barrels of natural cement, all manufactured in this country, and none requiring renewal on account of the poor quality of the cement used, are yet daily reminded that their cement is only a cheap article.

The testing machine is a good thing if put to a legitimate use. It is the abuse of it that we object to. It should occupy a subordinate place. The understanding of the proper use of the machine consists in knowing something of the chemistry of a cement, in knowing what a table of analysis means, in having a knowledge of true combining proportions, and of the effect of variations therefrom. Then the testing machine becomes a valuable auxiliary, for its readings have taken on a new meaning.

A study of the tables of long-time tests of Portland cements as compiled by such engineers as Clarke, of Boston, and MacClay, of New York, and others eminent in the profession reveals the fact that briquettes of neat Portland cement do not test as high at three or four years as they do at one or two years old. I have seen works that were made with Portland cement concrete remain in perfect condition for eight years, and during the ninth year go all to pieces. The ten-year tests of Portland cement made by Dr. Michaelis, of Berlin, show that the maximum strength was reached at the end of two years, and this point held fairly well until the end of the seventh year, but from that time until the end of the tenth year there was a remarkable falling off in values.

During the past summer the engineer in charge of the Aberdeen harbor sea works reported a serious failure in the Portland cement concrete works at that point. After only fifteen years' immersion it went to pieces, while the natural cement concrete, at the same place and the same age, was in good condition. After a thorough examination by a board of engineers, assisted by Professor Brazier of Aberdeen University, it was concluded that "Portland cement cannot resist the action of sea water." Another case is that at the harbor of Dundee, reported upon during the past summer. In this instance the Portland cement concrete had softened in sea water, and natural cement was used to protect it if possible from further disaster.

The investigations of Professor Tetmajér, of the Federal Polytechnical School, at Zurich, developed some interesting information. It has long been noticed in Germany that Portland cement of certain

class cement that can surpass in durability that which nature has so bountifully bestowed upon us.

An interesting and lengthy discussion followed the reading of the paper, after which the meeting adjourned with a vote of thanks to the speaker.

MEETING 367.

The Strong Locomotive.

BY MR. GEORGE S. STRONG.

The 367th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Dec. 8th, at 8 P. M., Mr. C. J. H. Woodbury in the chair.

After the reading of the records of the previous meeting, the chairman introduced Mr. George S. Strong, of New York, who read a paper on "The Strong Locomotive."

Mr. STRONG said: The Strong locomotive is the result of a determination to overcome the chief defects in the ordinary locomotive without, at the same time, introducing any radical differences of principle or general appearance, and it is generally conceded that the two main defective parts of a locomotive are the boiler and the valve gear. The demand now is for high speeds, and it is certain that the long distances to be traveled in America require a high speed service more than the short runs in England.

First, the boiler. It is by no means impossible, with a rectangular fire box, to obtain as large a fire grate as may be desired, but this is done at the expense of safety. The flat-sided box, with its multitude of screw stays, is not a scientific form of construction, but one which contains the elements of self-destruction, as the thousands of broken stays constantly testify. Hence, as regards the boiler, there is required some structure providing a larger grate area than hitherto has been safely employed, and constructed on recognized safe and scientific principles. Modern practice calls also for higher pressures,

fuel per horse power than by seeking to increase the tractive power at speed per pound weight of machinery. The question of efficiency per pound weight of motor has been far too little studied, and it is acknowledged that an engine which secures a high efficiency, and does so without loss of economy, is a machine worth some consideration, and such is the Strong locomotive.

To run a heavy train at high speed requires a large power, and this implies a high mean cylinder pressure and a continuous and well sustained steam supply, which are not obtained by the ordinary valve gear and rectangular fire box, but have been obtained in the Strong locomotive. Within the fire box shell are two furnaces which together give a grate surface about three times that of ordinary locomotives. The large area of grate renders possible a lighter blast, so that the fire is not torn up. Beyond the furnaces is a separate combustion chamber, in which combustion is completed before the gases are quenched in the small tubes.

The furnaces are of the type successfully introduced by Mr. Samson Fox of the Leeds Forge Company in 1878, and so largely used in marine practice. They are of steel, corrugated, so as to form a series of compound arches giving immense resistance against a collapsing pressure when rolled into cylinders, and are, for all practical purposes, indestructible, having been found capable of resisting a collapsing pressure of 1100 pounds per square inch. Hitherto the weakest, a locomotive fire box may now be made the strongest part of the boiler. The furnaces are united by a junction piece, or "breeches," to the combustion chamber, also of corrugated steel. The riveted junctions lying in the path of the flame from the fires are Adamson flanged seams, a form which provides that no rivet shall be exposed to the action of the fire, and is now in almost universal use in English boiler practice. We have in this boiler endeavored to avoid all transverse stress, and trusted to the direct tensile and compression strength of the material. The barrel of the boiler, being like the furnace and combustion chamber welded at all longitudinal seams, presents no material points of difference from the ordinary boiler, but back of the barrel the difference is very great. In place of the flat-sided fire-box shell, with circular top, we have two segmental pieces joined by a stout central or division plate. Each segmental half of this shell acts, therefore, just as though it were a

complete circular shell, for the division plate has, of course, pressure on both sides, and acts by tension only to resist the bursting stress on the cylindrical segments. The welding of the longitudinal seams has been made possible by the introduction of gas for such purposes, which enables us to heat up the welding scarfs to the proper temperature and preserve their surfaces clear and free from dirt, oxidation, or anything which might tend to make the weld less reliable than the rest of a plate. By welding, too, we may have perfectly circular barrels not otherwise obtainable without butt jointing and double covers, and so we avoid any tendency to grooving.

The back head is the only portion, except the tube plate already referred to, that is exposed to pressure and yet flat. As, however, it is chiefly occupied by the furnaces, this is of small account, and a slight gusset stiffening is all that is required as staying, and forms with similar staying of the front tube plate all the staying in the boiler. As now constructed, every part of the boiler may be machine riveted. It is thus seen that we have a boiler fully capable of supplying all the steam required from it, and the only remaining problem is to devise an engine to suitably utilize this steam.

As before mentioned, the old link motion does not meet the requirements. It is desirable in a valve motion to avoid sliding parts, and secure pin joints only. It is desirable also that the waste spaces or clearances in the cylinders be as small as is consistent with due area of ports and passages. Modern steam engineering demands not only separate valves for steam and exhaust, but also independent regulation of exhaust valves.

The problem, then, was to design a valve gear in which the steam and exhaust valves shall be moved separately, so that full advantage might be taken of the benefits of both cut-off and moderate compression. These requirements have been fully attained in the gear adopted. In place of a single slide valve, four valves, all alike, are employed for each cylinder, two for steam and two for exhaust. They are of the gridiron, or multiported type, and work up and down when in full gear only $1\frac{1}{16}$ inches vertically. The actuating gear consists, for each cylinder, of a single eccentric only, to the strap of which are attached the two eccentric rods. One of these, for steam valves, is rigidly attached to the straps; the other, for the exhaust, is pin-jointed. Each rod is suspended at a point

eight inches from its extremity by a long link to a block, which slides upon a quadrant. Each block may be placed at any desired position on its quadrant by means of the reversing levers, and so decide the point of cut-off, and whether the engine shall run forward or backward. From the eccentric rod ends motion is taken through the connecting link and bell crank arm and horizontal rod to the valve levers or rockers. The result of this peculiar arrangement is to give a rapid opening and closing of the steam and exhaust ports, and to cause each valve to stand almost still during half of each revolution of the eccentric. The gear is very simple and readily comprehended. It has no working parts other than cylindrical pin joints, and therefore works with a minimum of wear and tear.

The seats in which the valves work are turned cylindrical plugs which fit in bored chambers cast in the saddle of the cylinder in place of the usual steam chest. Suitable grooves are cut or milled out in the seats and arranged to fit the valves. In each valve of a 20 x 24 or 19 x 24 inch cylinder are 10 ports, each 4⅝" long by ⅜" wide. The steam edge is, therefore, 46¼ inches long, or nearly three times that of an ordinary valve. By this long admission edge the initial cylinder pressure very closely approaches that in the boiler, and the rapid opening of the port and equally rapidly closing insure that the initial pressure shall be well maintained and cut-off sharply defined. The same applies to the exhaust also, which may be kept open until just such point as will give a proper, but not excessive, compression. An ordinary locomotive at early cut-off loses about a third of its proper mean effective pressure, from excessive compression, and this necessitates a later cut-off, and, perhaps, a threefold expansion only, in order to maintain the mean pressure we secure at a sixfold expansion.

We are thus enabled to obtain a greater tractive force per pound weight of engine, and instead of, as now, an engine being far too heavy for its work at high speeds, we are able to more fully utilize such weight by the conveyance of a greater load at equal expansion. (Various indicator cards were shown from a Lehigh Valley engine with the Strong valve gear, and from an engine of the Lehigh Valley road which is a good example of a link-motion engine, showing differences in favor of the former.) Generally, it may be said that wheel diameters are too small in America, and it is an advantage of

work hitherto never done, except by two locomotives. It will haul twenty cars at sixty miles speed on a level, and keep it up. For fast work, however, larger wheels than 62 inches are to be preferred.

The plates herewith show clearly the various details of the locomotive.

The meeting was adjourned, with a vote of thanks to the speaker for his very instructive paper.

MEETING 368.

Recent Improvements in Systems of Electrical Distribution.

BY MR. WILLIAM STANLEY, JR.

The 368th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Dec. 22nd, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting and the election of new members, the President introduced Mr. William Stanley, Jr., Electrician of the Westinghouse Electric Light Co., of Pittsburgh, who read a paper on "Recent Improvements in Systems of Electrical Distribution."

Mr. STANLEY first gave a brief account of the early history of electrical development, alluding to the efforts of Sir William Siemens of England and Mr. Charles F. Brush of our own country in 1870. To the latter gentleman we are indebted for the practical development of the series of arc systems of lighting. Following closely upon the introduction of the arc light came the development of the incandescent lamp by Sawyer and Edison of this country and Swan of England.

Small wires were at first used, and they were gradually changed to larger ones until the cost of these conductors became a matter of most serious consequence; amounting, in fact, to the prohibition of

difference of potential, or E. M. F., in this particular case is 300 volts. The weight or cost of conductor for a given distance relative to the weight and cost of a conductor for the same number of lights at 100 volts, and with the same percentage of loss, would be inversely as the square of 100 is to the square of 300, that is, inversely as 10,000 is to 90,000, or directly as 9 is to 1. So that this conductor would cost one-ninth of the conductor for 100 volts.

This system, however, possesses the disadvantages incident to series distribution.

The other system of Brush is the Series Multiple.

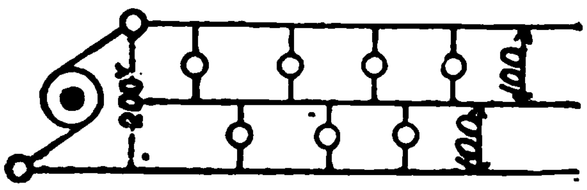


Fig. 2. Brush Series Multiple.

In this particular case the difference of potential is 200 volts. This system is admirable in comparison with anything already described. It is practically a multiple arc 200-volt system, requiring one-fourth the quantity of copper used with the 100-volt distribution. So long as the number of lamps on each side of the center wire is equal, it works perfectly, but as this is rarely the case, means must be provided for compensating for the excess of current upon the side having the lesser number of lamps in circuit. Mr. Edison has designed a very simple and beautiful arrangement for this purpose.

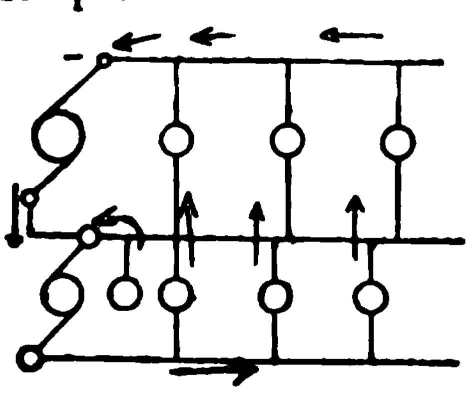


Fig. 3. Edison 3-Wire System.

Here two dynamos, each of 100 volts, are connected in series; the two outside terminals are connected to the two principal mains, and the center connection between the dynamos is attached to the middle or third wire. The excess of current on one side over the current on the other side returns by the third wire to its generating dynamo, as indicated by the arrows. The cost of the conductors, relative to the 100-volt distribution, is, for the two outside mains, 25 per cent, and for the center main about 15 per cent. or 40 per cent in all, of the 100-volt distribution. So that the saving by the Edison three-wire system amounts to 60 per cent on 100-volt distribution.

The copper for 10,000 lamps, Edison three-wire system, at 3000 feet, with a maximum loss of 5 per cent in mains, would cost then about $126,480, which is still quite a considerable item.

We will now turn our attention to the results of the endeavors

In the spring of 1885, at the request of Mr. Westinghouse, of Pittsburgh, I began to look into the possibilities of the induction system. Naturally, I tried a series arrangement at first, but found the difficulties above mentioned. This work, however, bore as a result a clear conception of the counter effects occurring in the induction coil, and eventually pointed out the way to construct the system now in use in this country, which I shall have the honor to describe to you this evening.

The induction system of the Westinghouse Electric Company consists of an alternating current dynamo, constructed to develop an approximately constant E. M. F. of 1000 volts; also of means for exciting the field magnets, and for properly regulating the E. M. F. of current and potential indicators, to guide the attendant in charge of the dynamo; besides a multiplicity of station details which, although apparently unimportant, are necessary to the proper equipment of a central station; but the particular feature of this system, which distinguishes it from previous systems of high potential distribution, is the induction coil or converter, as I have called it. Induction, or the development of an E. M. F. without contact, occurs through the instrumentality of a magnetic field of force,— that is, the field is the vehicle of the induced E. M. F. It is necessary to cause a variable relation to exist between the field and the conductor in order to develop an E. M. F. on it. A magnetic field of force is supposed to consist of magnetic lines of force,—the strength of the field being proportional to the number of lines. These lines of force surround a conductor, and it has been discovered that, if the number of these lines can be varied about a conductor, an E. M. F. will be developed on it proportional to the rate of variation in the number of lines; thus, if we have two conductors side by side, the one connected to a dynamo whose current varies, we will induce an E. M. F. upon the neighboring wire. An apparatus thus constructed is called an induction coil.

The best induction coil—that is, the one in which the loss through induction is least—is a coil in which every line of force surrounding the conductor in which it is developed also surrounds every other conductor upon which it is to impress its E. M. F.

There have been many designs of induction coils, but the best ones are very much alike. In the Westinghouse Electric Company's

a loss of two per cent, the cost of main for the three-wire system would be $156, while for the induction system it would be $3.60, to which must be added the cost of converters, $1500, making a total of $1503.60.

For large central stations with the induction system, we may neglect the cost of conductors, and compare only the cost of the converters with the cost of mains of any direct current system yet devised; and it is in this branch of electric lighting that the distribution by means of converters is an advance over any other system now in use.

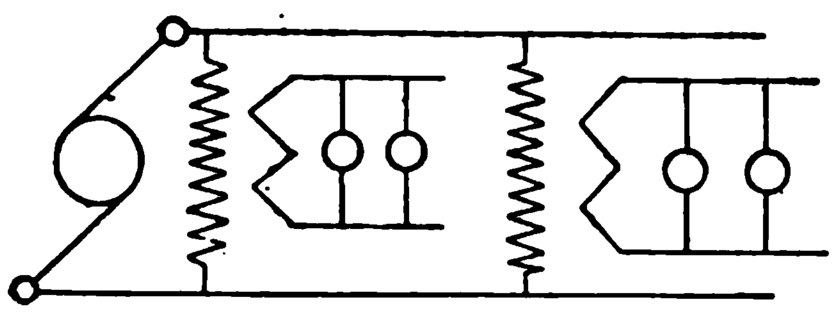


Fig. 5. Westinghouse System.

In the Westinghouse Electric Company's system, the dynamos are run at such a speed as to give about 16,000 alternations per minute, or about 266 alternations per second. With this number of alternations, the loss in conversion, other than that due to the current overcoming the resistance of the primary and secondary wires, is very small. There is unquestionably a loss due to simple magnetization and de-magnetization of the iron core, but it is so small as not to enter into the calculations on converters.

I have noted a few cases of the cost of distribution between the two principal systems now in use in this country.

Edison "3 wire" 200 Volt System				1000 Volt Induction System.		
Per ct. of loss in Mains.	Distance.	No. of Lamps.	Cost of Mains.	Cost of Mains.	Cost of Converters.	Total.
2	1000	1000	$3,511	$84	$3,000	$3,084
5	1000	1000	1,347	33	3,000	3,033
2	1500	1000	7,910	197	3,000	3,197
5	1500	1000	3,156	78	3,000	3,078
2	2000	1000	13,952	330	3,000	3,330
5	2000	1000	5,675	141	3,000	3,141
2	4000	1000	56,282	1,407	3,000	4,407
5	4000	1000	22,512	562	3,000	3,562

From this table we see that, at the present cost of converters, the two systems cost the same, with two per cent loss at 1000 feet distance, with five per cent loss at a distance of 2500 feet distribu-

ment the potential was not equally distributed throughout the length of the coils. For instance: the inner turns on the Ruhmkoff coil, whether primary or secondary, have a greater difference of potential per turn developed on them than have the outer coils, more distant from the core; while in the modern converter, if the difference of potential, either impressed or developed, be of a given value for one turn of wire, the same value is developed or impressed on every other turn. Consequently, the fundamental law of the converter is the E. M. F. on any portion of wire in a converter is proportional to the number of turns.

There is no such law applicable to the older type of instrument. This new result in the induction coil is obtained in the simplest manner. It is evident that with a given rate of changes of magnetic field the E. M. F. developed in a conductor is measurable by the number of lines of force encircling it. Now, if we can arrange our conductor so that every line of force surrounding one portion of it surrounds all other portions, the E. M. F. developed on equal lengths of the conductor will be the same. In the older forms of coils this did not occur because of magnetic leakage.

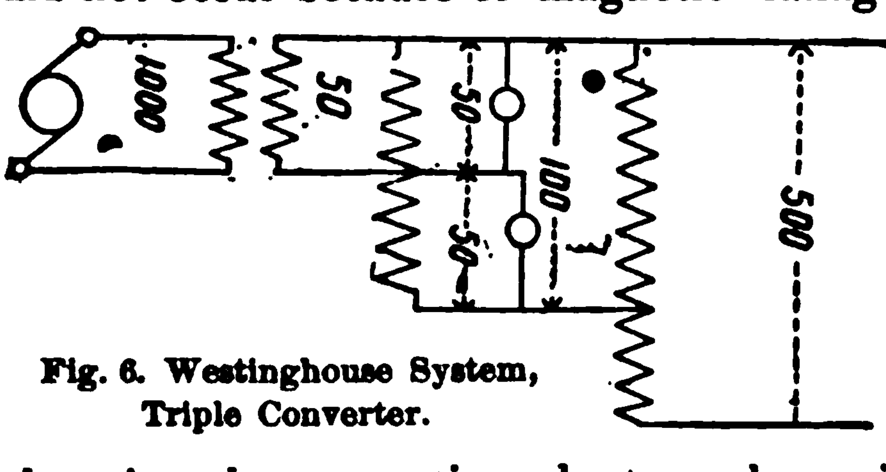


Fig. 6. Westinghouse System, Triple Converter.

One of the chief advantages attending the use of the induction coil for purposes of distribution is the facility with which any E. M. F. may be produced on the spot; that is, without changing the generating plant, as shown in figure 6.

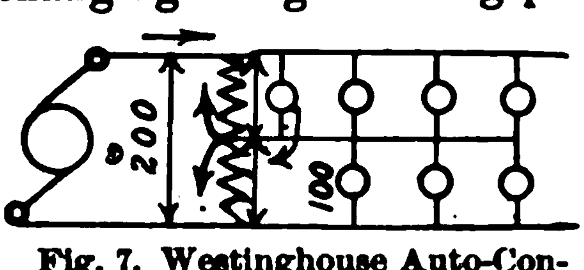


Fig. 7. Westinghouse Auto-Converter System.

In order to use the induction coil most economically for certain purposes, especially in case when the E. M. F. is not dangerous to life, I devised the method shown in Fig. 7.

You will notice in this case the E. M. F. applied to the coil is 200 volts; while the E. M. F. between the outside and intermediate terminals is 100 volts. Now, this single coil will regulate for and take care of many times the number of lights that the same sized coil would care for if wound with two insulated circuits, one primary and one secondary.

After the reading of the records of the previous meeting, the chairman introduced Prof. W. T. Sedgwick, of the Institute, who read the two following papers: —

FIRST. — A BIOLOGICAL EXAMINATION OF THE WATER SUPPLY OF NEWTON, MASS.

Prof. SEDGWICK said: The city of Newton gets its water from a filter basin 1575 feet long, running alongside the Charles River in the town of Needham. The water in the filter basin is pumped by engines in a pumping station near by to a reservoir some four miles distant on Waban Hill, from which it flows by gravity to all parts of the city. In the spring of 1887 the authors made in the Biological Laboratory of the Institute of Technology a quantitative bacteriological examination of the water from the Charles River, the filter basin, the reservoir on Waban Hill, and the tap in the city of Newton, estimating carefully the number of bacteria and molds in equal samples of water taken from the different localities on the same successive days. At the same time Mrs. Richards and Mr. Bartlett carried on a chemical examination of similar samples in the Institute Laboratory of Sanitary Chemistry. In the course of the investigations 145 biological and 117 chemical analyses were made; and all the work was done between April 1st and May 15th.

The method employed in the biological examinations was the well-known gelatine plate-culture method of Koch. The usual accessory apparatus was employed, and need not be described. The principle underlying the method is this: By mixing a known volume of the water under examination with a much larger volume of so-called "sterilized nutrient gelatine," the germs in the water are first *separated* somewhat widely from each other in the melted gelatine; and afterward, when the gelatine has been poured out on a cool plate carefully leveled, are *kept* separate and isolated by the stiffened mass. They are thus held securely apart, but may still easily grow and multiply in the nutrient mass, enriched as it is by meat extract, peptone, etc. At first the gelatine appears perfectly clear and pure; but after a day or two, comparatively opaque whitish or yellowish dots or islands may be detected, due to the rapid, though localized, increase of the germs. Each of these dots, if caused by bacteria, is

BACTERIOLOGICAL COMPARISON OF THE TAP WATER OF NEWTON AND BOSTON (BACK BAY) DURING ONE WEEK.

Date.	Colonies per c. c., Newton.		Colonies per c. c., Boston.	
	A	B	A	B
May 6.	0	4	48	60
" 7.	6	12	30	44
" 8.	Sunday.	Sunday.	Sunday.	Sunday.
" 9.	8	14	40	52
" 10.	0	4	24	60
" 11.	2	4	28	32
" 12.	0	8	25	35
" 13.	12	15	55	65
Averages . .	6		43	

Average number of bacteria per c. c. found in the water from

Newton (tap)	6
Boston (tap on the Back Bay)	43
Mystic (tap in Charlestown)	204
Spot Pond (pond)	38
Spot Pond (tap in Malden)	10
Jamaica Plain (Boston High Service)	52

The first table shows a considerable and constant difference in the abundance of living bacteria in the several waters examined, and indicates a progressive purity in this respect as the water nears the point of consumption. The largest difference between successive samples is that between the river water and that in the filter basin, and this is easily explained by a consideration of the conditions prevailing in each. The river is an ordinary stream, draining a rather thickly inhabited country, and hence is more or less polluted. The filter basin on the contrary, although dug parallel to the river and near it, probably gets from it little or no water. This comes instead from the other direction, owing to the slope of the adjacent country; and especially from eight artesian wells driven in its bottom to a depth of thirty feet, where they penetrate a quicksand and a gravel overlying bed-rock inclined toward the river. Thus it comes about

CHEMICAL ANALYSES OF THE NEWTON WATER SUPPLY.

PARTS PER 100,000.

	Charles River.		Filter Basin.		Reservoir.		Tap.	
	Free Ammonia.	Albuminoid Ammonia.	Free Ammonia.	Albuminoid Ammonia.	Free Ammonia.	Albuminoid Ammonia.	Free Ammonia.	Albuminoid Ammonia.
Apr. 1	.0070	.0250	.0150*	.0078				
" 6	.0030	.0212	.0014	.0088				
" 11					.0018	.0100		
" 18	.0046	.0254	.0038	.0118	.0320†	.0158	.0018	.0056
" 27	.0012	.0264	.0018	.0138	.0036	.0096	.0004	.0080
May 1	.0014	.0264	.0026	.0126	.0030	.0130	.0004	.0050
" 9	.0050	.0194	.0004	.0120	.0016	.0094	.0012	.0063

On April 1st the ice had just begun to break up.

* Possibly due to melted ice, or to the fact that the water under the ice is more nearly stagnant.

† Taken just after a snow storm. The banks of the reservoir had also been recently dressed with fertilizer.

SECOND. — A NEW METHOD FOR THE BIOLOGICAL EXAMINATION OF AIR.

The authors were led to devise a new method for the biological study of the air in order to overcome, if possible, the obvious defects of the methods hitherto in use. The principal methods so far employed are: —

1. *Hesse's*, in which a known volume of air is drawn through a long tube coated inside with sterilized nutrient gelatine, upon which the germs may fall and grow and afterwards be counted. The chief defect here is that some germs pass through and are lost, only the heaviest being detained.

2. *Frankland's*, in which the air is drawn through sterilized glass wool, powdered glass or some other substance, and is thus filtered; after which the filter or plug containing the germs is transferred to a flask of melted sterilized nutrient gelatine, shaken thoroughly, and the whole cooled down. The germs are thus fixed, but mixed with the gelatine, and may be counted in the usual way. Several defects exist in this method,— notably the possibility of loss

MEETING 370.

Steam Engine Experiments in the Mechanical Engineering Laboratory of the Mass. Institute of Technology.

BY MR. A. J. PURINTON.

A General Review of Steam Engine Tests.

BY PROF. C. H. PEABODY.

The 370th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Jan. 26th, at 8 P. M., Hon. J. A. Dresser in the chair.

After the reading of the records of the previous meeting and the election of new members, the chairman introduced Mr. A. J. Purinton, who read a paper on "Steam Engine Experiments in the Mechanical Engineering Laboratory of the Mass. Institute of Technology."

Mr. PURINTON said: In making a test on any engine, the principal things we want to find are the amount of work done by the engine and the amount of steam which it takes to do that work, and these two things taken together will tell us if the engine is working economically.

To find the work the engine is doing we usually make use of the steam-engine indicator, which gives, by means of its peculiar construction and connection with the cylinder and cross-head of the engine, a closed curve, and from the enclosed area we can find the work done, as will be spoken of later.

The amount of steam used can be accurately determined by condensing the exhaust steam and weighing it, or, by weighing the feed water before it enters the boiler. In this case the steam from the boiler should be used only for the engine. The former way is preferable to the latter, but of course requires the use of a condenser, which is not always available. The method of making and working up our tests is as follows: —

the cylinder will be heated to approximately that temperature. To do this, a certain amount of steam must be condensed, which accounts for the water present at cut-off.

Between cut-off and release, as the piston travels onward, the volume which the steam occupies is increased, thus reducing its pressure, and consequently its temperature. Then, as the temperature of the cylinder is higher than that of the steam and water in it, some of the latter is evaporated, giving a greater weight of steam at release than was in the cylinder at cut-off, although the weight of the mixture of steam and water is the same at both points in the stroke.

The indicator diagram shows also the pressure per square inch in the cylinder for every part of the stroke.

To get the mean effective pressure, that is, the average pressure per square inch on the piston for the whole stroke, the area of the card is divided by the length, the quotient being the mean hight. This hight is then multiplied by the number of the spring, and the result is the mean effective pressure.

The mean back pressure, if any, may be found in the same way. These results, together with the per cent of the stroke at which cut-off, release, and compression take place, are found for each card, and the average taken for the cards of each end, which gives two average cards, one for each end, from which the final results are calculated.

The piston displacement, that is, the area of the piston, multiplied by the length of the stroke, both expressed in feet, the clearance, given in terms of the piston displacement, and constant (horse-power for one pound mean effective pressure and one revolution per minute) have been determined beforehand for each end of the cylinder, and do not vary for any one engine.

The horse-power for each end of the cylinder is obtained by multiplying the constant by the mean effective pressure for that end, and this product by the number of revolutions per minute. The total horse-power is found by adding the horse-power for the two ends together.

To find the weight of steam at cut-off, its volume must first be found. The per cent of the stroke at which cut-off takes place is added to the per cent of clearance, and the sum multiplied by the piston displacement gives the volume of the steam which expands as the piston moves onward.

From the results of the tests on the Porter-Allen and Harris-Corliss engines, a number of curves have been plotted, and were shown on the screen, from some of which it was seen that the amount of water consumed decreased quite rapidly at first as the horse-power increased, and afterwards much more slowly, which shows the disadvantage of running an engine with a very light load. When running the Porter-Allen at 20 horse-power, the water per horse-power per hour was 70 pounds, and when running at 45 horse-power it was less than 40 pounds. In the same way with the Harris-Corliss, at about 5 horse-power the amount of water used was between 55 and 60 pounds, while at 12 horse-power it fell to 38 pounds. The largest and smallest amounts of water per horse-power per hour, shown by the Porter-Allen tests, were 70.7 and 37.4 pounds, with 20 and 40 horse-power respectively. For the Harris-Corliss the largest was 58 pouuds with 5 horse-power, and the smallest 35 pounds with 11 horse-power.

Other curves showed that the per cent of the mixture shown as steam increased as the length of the cut-off increased, and that the per cent shown at cut-off increased much more rapidly than at release.

Still other curves showed that at first the amount of water decreased quite rapidly as the cut-off was lengthened, and afterward more slowly, up to 35 per cent, which was the maximum obtained in these experiments. These also showed that the effect of lengthening the cut-off was the same on both engines, although one runs at 200 revolutions per minute, while the other runs at only 60 per minute.

Other curves showed that for a short cut-off the reëvaporation was very great, and that it decreased very rapidly as the cut-off was lengthened; the Harris-Corliss giving a reëvaporation per horse-power per hour of 31 pounds for a cut-off of 9 per cent, and only about 4 pounds for a cut-off of 30 per cent; the shortest cut-off of the Porter-Allen engine, 16 per cent, showed 19 pounds, and the longest, 36 per cent, a little less than four pounds.

A GENERAL REVIEW OF STEAM ENGINE TESTS.

At the close of Mr. Purinton's paper, the chairman introduced Prof. C. H. Peabody, of the Institute, who read a paper on "A General Review of Steam Engine Tests."

which made it more convenient to make the omission than to try to make some allowance for such an action. Even today we cannot be said to have any further information than that the action of the walls is energetic, and that it takes place in a fraction of a second.

The only proper solution of such a difficulty is by means of experiment, but an investigation shows a surprising paucity of material. Even what does exist is more qualitative than quantitative.

Tests may be divided into two classes: those for commercial and those for theoretical purposes. The first determine the cost in money or in coal of doing certain work. The second require that enough data should be obtained to completely solve the problem of the behavior of steam in the engine.

Of the first class we have a large number. Any reputable maker of pumping engines will guarantee a certain duty, and large engines of all classes are frequently contracted for on the basis of a certain coal consumption. In either case a test is made to prove the performance. In attempting to use the results of such work for theoretical purposes, we are at once confronted by the lack of sufficient data, even when the work is done with a care and accuracy that would otherwise be quite sufficient. Formerly no attempt was made to separate the action of the boiler and the engine; but now it is customary to make such a separation, even when the coal consumption is the ultimate object sought, by determining the consumption of steam by the engine in pounds per horse-power per hour. When enough other data are given this gives the basis for the calculation of the consumption of heat, measured in heat units, which is the logical measure of the efficiency of any form of heat engine.

The steam consumption may be determined by weighing or measuring the quantity of feed water supplied, when steam is supplied to the engine undergoing test alone. In such work the use of a water meter is to be deprecated, and the data of a test when a meter is used are of value only when that individual meter is subjected to careful and extensive tests to determine its errors.

Should the engine have a surface condenser the condensed steam may be measured instead of the feed water, and a test may be of less duration, since the flow of water from the condenser is more regular than the supply of feed water, and because the total quantity of water in the condenser is so small that a considerable variation

TABLE I.

TEST ON SMALL ENGINE, $5\frac{1}{2}'' \times 10''$.

	Saturated Steam Jacket off.	Saturated Steam Jacket on.	Superheated Steam Jacket on.
Steam per indicated H. P. per hour.	79.5	51.9	42.4
Per cent not shown by indicator.	65.7	54.3	44.9
Gain by jacketing or superheating.	48 per ct.	19 per ct.	

have an important effect on the action of the steam contained, and the conclusion is inevitable that the poor economy is due to the excessive condensation of steam in the cylinder. Such condensation is more noticeable in small engines than in large, since the area varies as the square, while the volume varies as the cube of the diameter, and the condensation must in some manner vary with the surface.

Recognizing this fact, Mr. Isherwood made a test on a large pumping engine, having a diameter of 90 inches and a stroke of 10 feet, and developing about 430 horse power, with 12 pounds pressure in the boiler. The engine made 42 strokes a minute, and had a cut-off at 62 per cent of the stroke. The engine was jacketed with steam on the sides but not on the ends. It was found that the consumption of steam per horse-power per hour was 36.4 pounds when the steam jacket was not used, and 35.4 when it was in use. The per cent of steam not shown by the indicator in the first case was 14.30 per cent, and in the second case, including that condensed in the jacket, was 11.98 per cent.

These two tests are to be considered as extreme cases, and the true gain in practice from the use of a steam jacket is intermediate between that shown by them.

In 1861 experiments were made by a board of U. S. naval engineers on the engine of the U. S. paddle-wheel steamer *Michigan*, to determine the most economical point of cut-off under conditions of the use of steam in engines of its class. The diameter of the cylinder was 36 inches, and the stroke was 8 feet. It made from 11 to 20 revolutions during the test, and developed from 60 to 340 horse-

The use of steam superheated about 96° F. above the temperature in the boiler at one-half stroke cut-off was accompanied by a gain of about 20 per cent. When the cut-off was at 58 per cent of the stroke, superheating 123° F. gave a gain of about 15 per cent.

The table shows a steady decrease of the quantity of water in the cylinder at the end of the stroke as the cut-off is increased for each series of experiments. The effect of the superheating is clearly to reduce the quantity of water in the cylinder at the end of the stroke, and it is readily inferred that this is the reason for the greater economy with the use of superheated steam.

Now, the water at the end of the stroke has thus well served to call our attention to the action of the walls of the cylinder on the behavior of the contained steam; but, as was shown by the tests in the laboratory of the Institute, it tells but a part of the story, for, during the expansion of the steam after cut-off, much of the steam previously condensed is reëvaporated. It may be worth while to stop and consider what is the true action of the walls of the cylinder on the steam.

At the beginning of the stroke the steam from the boiler comes into the clearance space at the end of the cylinder and the steam passages, a space which from its form has a large surface for its volume, and is condensed upon the surface with exceeding rapidity. During the stroke new cool surfaces are uncovered by the piston, and the condensation goes on up to the point of cut-off, or a little beyond. After cut-off the pressure is reduced by expansion till it is less than that corresponding to the boiling point of the water condensed on the walls of the cylinder and adhering to them. That water is consequently evaporated in part at the expense of the heat acquired by the walls during its condensation. At the end of the stroke the pressure suddenly drops to that of the condenser or the atmosphere, and nearly if not quite all of the remaining condensed water in the cylinder is vaporized, and takes from the walls of the cylinder the remainder of the heat acquired during admission of steam to the cylinder. The action of the walls during the compression we may neglect for the present, for it is small when the compression is small, as in the Corliss engines.

Of the heat acquired by the walls of the cylinder during admission, a part is restored during the expansion, on account of the

form designed by Hirn to use superheated steam, and the other of the Corliss type, which was provided with a steam jacket, and used saturated steam.

The data of the experiments are very complete, though unfortunately only a part of them appear to be accessible since the death of Hallauer; in all other cases the results only are at hand.

Three of the experiments, which appear to be comparable and which bring out the points for which we are looking, are given in —

TABLE IV.

EXPERIMENTS ON HIRN AND CORLISS ENGINES.

	Horse Power Cheval-à-Vapeur.	Steam per H. P. per hour. Kilograms.	Cut-off.
(1) Hirn-Superheated.	144	7.6	1-4
(2) Hirn-Saturated.	136	9.3	1-4
(3) Corliss-Jacketed.	158	7.8	1-6

Per cent of Water in Cylinder.		Exchange of heat in per cent of total heat furnished per stroke.		
Cut-off.	Release.	Absorbed during admission.	Restored during expansion.	Wasted during exhaust.
6.5	12.0	11.0	2.0	7.8
30.4	25.2	23.9	7.3	15.4
25.3	18.5	15.4	10.4	8.0

The Hirn engine using superheated steam has a slight advantage in consumption over the Corliss engine. The Hirn engine using saturated steam has a much greater consumption than either of the two other experiments. No experiments were made on the Corliss engine without its jacket, but it would probably give a like result under such condition.

The quantity of water in the cylinder at the end of the stroke, and the heat wasted during exhaust, give a ready explanation of this diminished efficiency, the latter quantity being nearly the same for each engine in its economical working condition.

Continuation of Table V.

	Per cent of Water in Cylinder.		Steam per H. P. per Hour.	
	Cut-off.	Release.		
1.	52.2	32.4	48.2	
2.	35.9	29.3	42.2	
3.	27.9	23.9	45.3	
4.	27.9	18.3	35.2	
5.	13.6	13.6	31.7	
6.	8.9	11.5	35.8	

In addition to the large gain by the use of superheated steam at 50 pounds pressure used during the experiments, the notable fact appears that a large degree of superheating in the steampipe is accompanied by a very moderate increase of temperature in the cylinder. At the most economical point of cut-off, namely, 44 per cent of the stroke, the balancing of evaporation and condensation during expansion is quite perfect.

In 1870 the U. S. Coast Survey steamer *Bache* was built with a tandem compound engine, having a steam jacket on the large cylinder but none on the small cylinder, as it was inconvenient to arrange for one on that cylinder in its position over the large cylinder. The cylinders had diameters of 16 and 25 inches and 25 inches stroke. An arrangement was made by which steam could be carried directly from the boiler to the large cylinder in case it appeared desirable to do so. The results of tests on this engine in its normal condition, working compound with steam in the jacket, are given in Table VI.

TABLE VI.

EXPERIMENTS ON THE BACHE,
PRESSURE 80 POUNDS, REVOLUTIONS 50.

Total number of Expansions.	Steam per H. P. per Hour.	Accounted for by Indicator.		Condensed.	
		Small Cylinder.	Large Cylinder.	In Jacket.	In Receiver.
16.8	25.1	58	74	6.5	11.2
9.2	20.7	68	76	7.	10.
7.0	20.3	74	73	5.1	7.6
5.7	22.	72	73	5.4	6.9
4.2	21.	82	77	4.	5.0

During the experiments the steam condensed in the receiver between the small and large cylinders was drawn off and weighed separately; had it passed on into the large cylinder, much of it would have been evaporated in that cylinder. When steam passes in that way from one cylinder to the other, it is commonly drier in the large cylinder than in the small cylinder. In triple compound engines, in which the steam passes through three cylinders, it is much dryer in the large or low pressure cylinder if the condensation in the intermediate pipes and receivers is not excessive.

The results of experiments made on the engine with the steam led to the large cylinder directly, and with steam in the jacket, are given in Table VII.

TABLE VII.

EXPERIMENTS ON THE BACHE, SINGLE.

WITH JACKET.

Total Expansions.	Steam per H. P. per Hour.	Steam Shown by Indicator.
12.6	27.1	61
8.6	24.1	64
5.1	23.1	70
2.2	34.0	71

WITHOUT JACKET.

Total Expansions.	Steam per H. P. per Hour.	Steam Shown by Indicator.
11.8	35.1	60.0
7.6	29.6	55.5
5.3	26.2	66.1

A comparison of Tables VI and VII shows that the largest number of expansions for the single engine should be 5, but for the compound engine may be from 7 to 9. Under these most favorable conditions the water at the end of the expansion to be evaporated during exhaust will be for the simple engine 30 per cent, while for the compound engine, allowing for the condensation in the receiver and the jacket, it is only 14 per cent. The gain from the greater expansion, and the reduction in the exhaust waste, are sufficient to explain the saving of 12 per cent in the consumption of steam.

In 1874 three U. S. revenue steamers were built on the same lines and were essentially the same, except that they were supplied with three types of engines, each engine being designed to give the same horse-power with the best economy for its type, and furnished with proper boilers.

The *Rush* had a receiver compound engine with cylinders 24 and 38 inches in diameter and 27 inches stroke, both cylinders being lagged and jacketed. The steam pressure was 80 pounds.

The *Dexter* had a single cylinder engine 26 inches in diameter and 36 inches stroke, lagged but not jacketed, using steam of 70 pounds pressure.

The *Dallas* had a single cylinder engine, 36 inches in diameter by 30 inches stroke, lagged but not jacketed, and using steam of 40 pounds pressure.

Without going into the details of the experiments, we may note the conclusions drawn from the experiments on these engines, and those on the engine of the *Bache*.

The high pressure engine of the *Dexter* had an advantage in consumption of steam of 13 per cent over that of the low pressure engine of the *Dallas*.

The compound jacketed engine of the *Rush*, using 70 pounds pressure of steam, had an advantage of 23 per cent over the single unjacketed engine of the *Dexter* using the same pressure. If it be assumed that the addition of a steam jacket to the engine of the *Dexter* would have been as efficient as that of the jacket on the engine of the *Rush* was shown to be when running single, then the advantage of the compound over the single engine would have been 13 per cent.

Now, in practice it is claimed that compounding is accompanied by a gain of 20 per cent. Mr. Emery, in reviewing these experiments, thinks that this is due to the fact that a large expansion in a single cylinder gives an undesirable distribution of work throughout the stroke of a marine engine. The engineer of the boat finds that a more advantageous distribution, which adds to his own convenience, can be obtained by lengthening the cut-off, and either reducing the boiler pressure or by partially closing the throttle valve. The accompanying reduction of economy does not deter him from doing so. On the other hand, the cut-off in a compound engine is seldom incon-

mended. To show the limit of steam engine performance, which may be approached but cannot be equaled, I will refer to Table VIII, which is calculated from Regnault's experiments by the accepted methods of thermodynamics, and which cannot be in error to the amount of one per cent, and which is probably correct to one-third of one per cent.

TABLE VIII.

Pressure.	Pounds of Steam per H. P. per Hour.	
	Condensing.	Non-Condensing.
15	15.4	51.1
30	13.6	32.8
60	12.8	22.9
100	10.9	18.9
150	10.2	16.0
200	9.8	14.6

MEETING 371.

The Manufacture of Paper, and its Uses.

BY HON. WM. A. RUSSELL.

Natural Gas.

BY PROF. L. M. NORTON.

The 371st meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Feb. 9th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting and the election of new members, the President introduced Hon. Wm. A. Russell, who read a paper on "The Manufacture of Paper, and its Uses."

presses, and especially the introduction of the Walter press in 1868, whereby paper could be printed in a roll at a much more rapid rate, demanded not only a large increase in the supply of paper, but paper made of a new material, one that would receive and absorb readily the quick-spreading ink. It was at this period that the much-mooted wood pulp came upon the stage. Previously little else had been used in this country for paper except cotton and linen rags and some straw. The introduction of the new material, though demanded, was looked upon with suspicion both by the paper manufacturer and consumer. The prejudice against any known substitute for rags was very strong, and it was with difficulty that the first newspapers were persuaded to give it a trial.

Mechanically made pulp is ground on an ordinary grindstone. The cellulose, starch, and other kindred elements are precipitated into pulp, and go directly into paper. This gives it a readily absorbent quality, a kind of paper which the rapid printing presses require. In fact, they would be absolutely helpless without it.

Chemical wood pulp, so called, is also largely manufactured in this country, and finds its way into a finer grade of paper, book, and writing papers. This pulp is produced by reducing the wood mechanically into small chips, and then boiling them with caustic alkali until the cellulose is rid of the starch and earthy matter which surrounds it, leaving the pure fiber.

Another step has recently been made in the production of chemical pulp by reducing it by an acid solution, etc., bisulphite pulp, so called, and a stronger fiber is obtained.

There is now manufactured in this country daily about 450 tons of mechanical pulp and 250 tons of chemical pulp. As each ton of this pulp represents about the same quantity of manufactured paper, it represents about double the quantity of old rags, as they shrink in working about one-half, so that, without this material, it would be impossible to obtain a sufficient quantity of rags to make the paper now consumed.

The price of paper has been very materially reduced by the introduction of wood pulp. Before the war the current price of newspapers was nine cents per pound; during the war it ran up to twenty-five and twenty-eight cents per pound. It has gradually fallen until now the ordinary newspaper is worth about 4½ cents, and book papers are in the same proportion.

a high per cent of the total average can be obtained. The advantages of a gaseous fuel are so great that many species of plants are in existence which are used to convert solid into gaseous fuel.

Nature, however, has accumulated vast stores of such fuel in the crust of the earth. This natural gas consists of hydrocarbons, and these under pressure, perhaps, permeate a considerable portion of the earth's crust. Where this state of things exists, a hole bored into such a stratum removes the pressure, and the gas rushes out, perhaps traveling for miles through the roots to reach the opening. I shall not consider this question from the geological point of view, and in regard to the origin of the gas I can only say that no satisfactory theory has yet been proposed, but there seems to be no reason to suppose that the agencies which formed this gas have ceased to act or that they are limited to small areas, so that the chance of immediate exhaustion of the gas is very small.

The composition of the gas from various localities varies through certain limits.

The analysis presents great difficulties. The hydrocarbons present are mainly methune and ethane. Hydrogen is undoubtedly present in many of the gases.

The best gas equals theoretically per 100 cubic feet of gas, weighing 4¼ pounds, on an average eight pounds of carbon. Anthracite contains 90.93 per cent of carbon, so that 100 cubic feet of gas will equal in theoretical fuel value about nine pounds of anthracite.

Now, the practical fuel value, of course, varies according to the pattern of the boiler or combustion chamber, but I was told several times during my stay in Pittsburg that the available fuel value favored the natural gas. I have never been able to obtain any really satisfactory figures on this point, but it is safe to put the fuel value of one hundred cubic feet of gas, with a hot blast of the generative system, as equal to twelve pounds of steam coal, while the expenses attending the use of the gas are very small in comparison with those attending the use of the coal. It is a somewhat peculiar experience to approach Pittsburg in the early morning and find the gas burning in the village lamps. They never extinguish it. It is a novel sight to see a boiler room as clean as an engine room, and huge jets of gas underneath the boilers, controlled by valves, and one fireman for a half dozen great boilers, and that one reading a paper.

The factor of linear measure enters primarily into every problem of cubical contents or of volume, and in the determination of standards of weight, which is illustrated in the units adopted under the metric system of weights and measures.

As is well known, a gramme is the weight in vacuo of a cubic centimetre of distilled water at the temperature of maximum density, or about 4 degrees C., and a litre is equal in volume to a cubic decimetre, the latter being in linear measure one-tenth of the metric unit of length, the metre. Long before this system had an existence or even a name, the standard of weight of Great Britain has been the Troy pound, from which was copied the Troy pound used in this country, and which is defined as the weight of 22.794,422 cubic inches of distilled water at its maximum density (at a temperature of 39 degrees F., nearly), the barometer standing at 30 inches, while the standard pound avoirdupois, used as the commercial unit of weight in Great Britain and the United States, is the weight of 27.7015 (nearly) cubic inches of distilled water at a temperature of 39.2 degrees F., the barometer being taken at 30 inches, at the latitude of London, its maximum density at this place, and is equal to the weight of 7000 grains, a grain being the smallest unit in English tables of weight, and identical for both the Troy and avoirdupois pounds.

Under the authority of Kater, one cubic inch of distilled water at 62 degrees F. weighs 252.456 grains, the barometer also being taken at 30 inches; the standard inch for this determination being 1-36 of the Imperial yard, the latter derived from the length of a pendulum vibrating seconds of mean time in a vacuum at the level of the sea, at the latitude of London or Greenwich.

The ancient standard of weight in England was the grain, so called from being measured by the weight of a thoroughly dried grain of wheat taken from the middle of the ear, and this unique natural unit is perhaps no older than the table of English "long measure — three barley corns make one inch," these being placed end to end to form the basis of a standard of measurement for a nation!

We also find that the length of the arm of King Henry the First was considered the correct basis for a standard system of measurement, while earlier the human foot or the hand came in for their share in the effort to establish a standard of length for ultimate reference.

the unit of length is the centimetre, the unit of mass the gramme, and the unit of time the second, being referred to for the sake of brevity or simplicity as the C. G. S. System. (See *Enc. Brit.*, ninth ed., vol. xv, p. 668.)

The standard inch is the thirty-sixth part of the Imperial yard derived from the length of a pendulum vibrating seconds, thus introducing the condition of time, and the length of such a pendulum was by Act of Parliament, June 17, 1824, declared as being 39.1393 inches; the yard to be made up of thirty-six of these standard inches.

The Act legalizing this standard reads as follows: —

SECTION I. — Be it enacted . . . . . that from and after the first day of May, one thousand eight hundred and twenty-five, the straight Line or distance between the Centers of the Two Points in the Gold Studs in the straight Brass Rod, now in the Custody of the Clerk of the House of Commons, whereon the words and figures "Standard Yard, 1760," are engraved, shall be and the same is hereby declared to be the extension called a Yard; and that the same straight Line or Distance between the Centers of the said Two Points in the said Gold Studs in said Brass Rod, the Brass being at the temperature of Sixty-two Degrees by Fahrenheit Thermometer, shall be and is hereby denominated the "Imperial Yard" . . . .

SECTION III. — And whereas it is expedient that the said Standard Yard, if lost, destroyed, defaced, or otherwise injured, should be restored to the same length by reference to some invariable natural Standard; And whereas it has been ascertained by the Commissioners appointed by His Majesty to enquire into the subject of Weights and Measures, that the Yard hereby declared to be the Imperial Standard Yard, when compared with a Pendulum vibrating Seconds of Mean Time in the Latitude of London in a Vacuum at the Level of the Sea, is in the proportion of Thirty-six Inches to Thirty-nine Inches and one thousand three hundred and ninety-three ten-thousandths Parts of an Inch; Be it therefore enacted and declared, That if at any Time hereafter the said Imperial Standard Yard shall be lost or shall be in any Manner destroyed, defaced, or otherwise injured, it shall and may be restored by making a new Standard Yard, bearing the same proportion to such Pendulum as aforesaid, as the said Imperial Yard bears to such Pendulum.

the thickness of a film of water to the 1-500,000,000 of an inch; a force quite large when compared with the small amount of water which we are considering. The measurement of this minute thickness is based upon the varying colors exhibited in the soap bubble, using the length of any given wave. Probably before this extreme tenuity could be attained, there would remain only a single layer of molecules held together by their mutual attraction, giving as the estimated average diameter of a molecule the 1-500,000,000 of an inch, a dimension so infinitely minute as to be quite beyond our ability to realize.

Sir William Thomson, from a comparison of these phenomena, has estimated the limits of range or size of these minute molecules to be between 1-250,000,000 and 1-500,000,000 of an inch, and in order to give some conception of the "coarse grainedness," as he calls it, thus indicated, he has said that "if we conceive a sphere of water as large as a pea, magnified to the size of the earth, each molecule being magnified in the same proportion, the magnified structure would be coarser grained than a heap of small lead shot, but less coarse grained than a heap of cricket balls."*

The materials available for standards of length, taken in the order of the rate of their expansion under the same conditions of temperature, are wood, glass, platinum, gold, silver, iron, brass, and copper. Wood may be rejected at once for our purpose, though it does very well for yard-sticks and pocket-rules for every-day use. Glass has been and is now used in certain cases, though its great brittleness restricts its application, and the changes going on within its structure are now the subject of rigid investigation by Prof. Rogers, requiring time to prove its value as a material for standards.

Platinum was adopted as the material for the end-measure *Metre des Archives*, and also for the bars representing the line and end metre standards in Great Britain.

Gold and silver may be said to be excluded for various reasons, that of cost in the case of gold, and its extreme softness, and silver, because of its great affinity for sulphur.

The Russian standard of length, used for geodetic surveys, was constructed of iron, using conical pieces of tempered steel in each end. This bar has a length of seven feet.

* *How Molecules are Measured.* By Prof. Josiah P. Cook, of Harvard College.

measure bar, on each side of the center line of motion of the microscope plate, using one microscope, and comparing this fixed length with the constant quantity before referred to, which is the distance between the stops. Should the path be a curved one, the distance between the defining lines upon the bar will appear greater on one side than on the other in proportion to the amount of curvature existing. By means of the proportion of similar triangles thus formed, the lengths of the radii may be very accurately determined. By placing different standards on one side of the line of the stops, they may be, by being compared with a constant quantity, compared also with each other.

The subdivision of these standards of length is effected by the use of this same process,— the microscope plate sliding between fixed stops,— and which serves to beautifully illustrate one of the fundamental principles of science, that "things equal to the same thing are equal to each other," or that the relation of different lengths each to a constant distance establishes their relation to each other.

The foot may then be subdivided in the same manner into twelve equal parts, establishing the standard inch, and, further, to eighths, sixteenths, thirty-seconds, hundredths, or even to thousandths of an inch.

To illustrate this method, and to make plain the reason why these corrections so obtained are used, we can suppose a case of simply dividing a rod or a string into two parts. Now, we know that for whatever amount one part is longer than the other, one-half of this amount belongs to the shorter to make it exactly one-half the whole length of the rod or string; hence we have one-half the sum, or amount, of the difference, and subtracting each difference from this half sum would in one case give us a minus correction for the longer part, and a plus correction to be applied to the shorter. The yard has thus been subdivided within a limit of about one hundred-thousandth of an inch.

The necessity for the correct solution of this problem arose from the requirements of the Master Car Builders' Association, through their committee appointed to investigate and report as to the degree of accuracy desirable to be secured, and the best means of maintaining this accuracy in the standard thread, which was proposed by Mr.

By carefully setting the eye-piece micrometer line in coincidence with the initial line of the standard bar, and also upon the line on the plate referred to, with a definite amount of pressure exerted upon the surfaces of the "stops" or abutting faces, which are polished planes, by a spring contained within the plunger, a positive "zero" or starting point is obtained. This invariable initial position being thus secured for each size of gauge to be measured, it is only necessary to place between the faces of the stops, with the same amount of pressure, the gauge to be operated upon, and moving the plate until the rear microscope is again in coincidence with the line representing the required dimension, the correctness or variation is at once indicated within a limit of about 1-50,000 of an inch, the line upon the little plate being only about 1-25,000 of an inch in width, and the micrometer reading, being taken readily within one-half of this minute quantity, gives some idea of the rapidity as well as the accuracy of this method when applied to the inspection of size gauges which are to represent when finished standards for reference in actual practice in the tool room for every purpose where interchangeability is desirable.

The standard line-measure bar used in this connection is designated as P. and $W._5$ in the report of Prof. Rogers to the company, and has a correction in total length, at 62 degrees F., of only five millionths of an inch, while the correction for the greatest error in any subdivision is only 1-50,000 of an inch. It is made of hardened steel, and thus can be used to measure hardened steel gauges at any convenient temperature, providing, of course, that a constant temperature has been maintained for a time previous sufficiently long to ensure uniformity for both bar and gauge.

The production of the model set of standard gauges for the Master Car Builders' Association included the origination of a "master triangle," in order to make the proper gauges for the correct angle of the United States Standard thread. The object in view was to furnish a means of obtaining a triangle of definite size, which should be exactly two inches long on each side, and being equilateral must be equiangular; and being equiangular must consequently be one having angles of 60 degrees. The reason for having the sides just two inches long was that it was necessary to establish the width of the flat for each pitch of the various sizes of the Franklin Insti-

MEETING 373.

Chemical Examination of Drinking Water.

BY PROF. T. M. DROWN.

The Johnson Heat-Regulating System.

BY. MR. WM. F. CHESTER.

The 373rd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, March 22nd, at 8 P. M., Dr. H. P. Walcott in the chair.

After the reading of the records of the previous meeting and the election of new members, the chairman introduced Prof. T. M. Drown, of the Institute, who read a paper on "Chemical Examination of Drinking Water."

Prof. DROWN said: The result of the chemical analysis of a drinking water, as ordinarily expressed, cannot be said to carry its explanation with it. The layman notes simply that the figures express very minute amounts of substances which are generally unfamiliar. And when he is told that none of the substances are necessarily injurious in themselves, and, moreover, that a good water may, under certain conditions, give numerical results which are identical with a bad water, his faith in the value of a chemical examination may well be shaken.

Three elementary considerations must be borne in mind in discussing the question of a water supply for drinking purposes: —

1. There are no absolutely pure waters to be obtained in nature.
2. The impurities found in natural waters differ widely in character when considered from a sanitary standpoint.
3. The same impurity may have a varying sanitary significance according to its origin.

An illustration of this is offered in the following analysis: —

and lower levels until it flows into the sea. Some of it never reaches this destination; a portion of the surface water returns to the atmosphere directly by evaporation; a portion of the ground water evaporates through the intervention of plants; and another portion is retained in porous rocks, and enters into mineral combinations.

Our attention will be first claimed by the surface waters. When a rapidly-flowing brook passes over a rocky surface it has but little opportunity to dissolve either mineral or organic matter, and mountain water of this character is universally recognized to be of the highest purity. As it continues its course it may pass through a forest with a much diminished rate of flow, and dissolve the coloring matter of leaves and peat, and also some mineral matters which are in the soil. We see it again flowing over swampy ground into an obstructed valley, and thus forming a lake. Under these conditions of very gradual, almost imperceptible, movement there is opportunity offered for the growth of many plants and animal organisms which do not thrive in rapidly-moving streams, and the water acquires from these growths, perhaps also from their decay, a decided taste and odor, and acquires a still more pronounced color. Flowing from the lake, as a river of increased size, it passes through a highly-cultivated farming region in which there is a deep, loamy soil, well manured. This will contribute to the water matter of animal origin in a condition of advanced decomposition. Further, as it flows past villages and towns it receives the refuse products of human life, which we include under the general name of sewage, and also the waste products of slaughter houses, tanneries, dye works, and factories of various kinds, which contribute not only putrefying material but also mineral substances of various kinds.

If we turn now to the study of the progress and character of the waters below the surface, we find a very different condition of affairs. The water which sinks into a porous soil during a rainfall descends slowly downwards until it reaches the level of the water already existing in the soil, or until it reaches an impervious layer of rock or clay. There is water present in most porous, gravelly, and sandy soils which is slowly flowing onward to lower levels. Its motion is not perceptible to the eye, but it can easily be measured. It is this mass of water which we intercept and utilize in the shallow, household well, as well as on the large scale where numerous wells

solids." This means all the dissolved matter, both mineral and organic, and also the suspended matter if the water is turbid and not previously filtered. On heating this residue to redness we burn off the organic matter and obtain the "loss on ignition." Unfortunately, this heating may, in many cases, drive off some of the mineral contents as well as the organic, and this loss, as ordinarily obtained, does not give us even an approximate determination of the organic matter. Still, in surface waters, with low mineral contents, we can, by carefully controlling the conditions of the ignition, obtain a very fairly accurate determination of the organic matter in this way.

The "fixed solids" are obtained by subtracting the loss from the total solids. It represents the amount of mineral matters; but, as already implied, this determination is generally too low, on account of the loss being too high. These mineral matters consist mainly of sulphates, chlorides, carbonates, and silicates of the alkalies and alkaline earths. Chloride of sodium (common salt) is present in all waters, being dissolved from rocks and soils. Its amount is generally small, and when, therefore, we find it in large quantity, we suspect the presence of sewage, or the waste products of human life, which always contain a large amount of salt. In any case, therefore, of unusually high chlorine an investigation is called for into the source of the water to ascertain whether this chlorine came from rocks or soils naturally high in chlorine, or from salt blown inland from the ocean, or whether the salt used in domestic life was its source.

Broadly speaking, living matter has the power of converting inorganic substances into organized structures, but when the life is extinct then the organized matter reverts, by process more or less complicated, into the inorganic condition. For our purpose it will suffice to consider the organic matter we find in water to be compounds of carbon, hydrogen, nitrogen, and oxygen. In the process of decay the nitrogen is converted into ammonia, and ultimately into nitric acid, which combines with some of the bases present, — potash or lime, — forming what we call, in a general way, nitrates. These two substances, ammonia and nitric acid, are so easily detected and quantitatively determined, even when present in very minute quantities, that we use them as the basis of our investigation into the nature of the organic matter and the extent of the changes which it has undergone. Suppose we examine a water and find no

a sample of water at intervals of weeks or months, taking out a portion from time to time, and exposing the remainder to ordinary atmospheric conditions in the intervals, we can find out its rate of change. If we find that this rate is slow, or that there is no change at all, during a month or more, no development of free ammonia, and that the albuminoid ammonia remains constant in amount, then we may fairly conclude that the nitrogenous matter in the water is of vegetable origin. This is a condition of affairs that we often find in the brown waters of lakes and rivers which are uncontaminated with animal matter; or, if they were originally thus contaminated, then the animal matter has completed its changes consequent on decay, and disappeared as such from the water.

The final stage of the oxidation of organic matter is indicated when the nitrogen exists entirely in the form of nitric acid. There is an intermediate stage between ammonia and nitric acid, namely, nitrous acid, which combines with bases to form nitrites. It is possible that the formation of nitrous acid is not always in the line of progression to nitric acid, but that it may be also, at times, the result of a retrograde action from the action of organic matter on nitric acid, a condition of things which, when existing, it is of great importance to recognize. Until quite recently it was supposed that the direct action of the oxygen of the air, and of that in solution in the water, were the causes of the changes which have been described. But we now know that these changes are the indirect result of the vital action of minute organisms — bacteria — which feed on the organic matter, and in some way effect this change of the nitrogen into ammonia and nitric acid. Their activity is greatest in the soil near the surface, and in warm weather, and it is therefore in ground waters that we find the largest development of nitric acid and the most complete obliteration of the organic matter. The nitrates in river water, and in surface waters, are not generally high. Whether this is due to the fact that there are relatively fewer bacteria to the mass of water, or to their feebler activity in the light, or, again, to the fact that the nitrates formed are promptly absorbed by vegetable or animal growth in the water, cannot be said with certainty.

The practical question now arises, what do we actually learn from a chemical analysis as to the fitness of a water for drinking? The answer to this has already been intimated, namely, that a chemi-

and that we may have a large amount of dissolved vegetable matter in water without danger to health. This, however, applies only to vegetable matter derived from natural sources, and not to those derived from manufacturing operations. It looks as if the danger was in direct porportion to the *activity* of the change. Now, we know that many of the dark-brown waters which owe their color to vegetable matter are often very permanent, with no tendéncy to change on long exposure to the atmosphere. Under such conditions the bacteria of decay cannot be very numerous or active. This brown matter in solution in water yields, in the course of chemical analysis, "albuminoid ammonia," but it has probably no sanitary significance. There is more "albuminoid ammonia" in one cup of tea than in many gallons of a dark-colored pond water.

I have purposely omitted any reference to the mineral matter in solution in drinking waters. When this is excessive, the water has a distinct saline taste, and such waters are generally classed as mineral waters and reserved for medical use. Disregarding this class of waters, we may say that what we want to avoid in a drinking water is sewage, using the term broadly to mean the refuse products of human life and manufacture. Is a river which receives sewage at *any* point unfit for drinking for the rest of its course? How much impurity may remain in the water without its rejection as a drinking water? How far must a well be from a house or stable to be permanently safe? These are every-day questions, fair questions, too, to which an answer should be given, although it is impossible to answer them in the same brief compass in which they are asked.

It is reasonable to suppose that a small amount of pollution is not as dangerous as a large amount, and that great dilution of the polluting material may render it practically inappreciable. Thus, the sewage of Minneapolis and St. Paul, according to Dr. Smart, makes no impression on the waters of the Mississippi, even in close proximity to these cities. The sewage of Troy, according to Dr. Chandler, is practically lost by dilution and change when the Hudson reaches Albany. Nearer home, we have the case of the Merrimack receiving the sewage of Lowell and Lawrence without being seriously affected. A very different state of affairs exists when a large amount of sewage flows into a small stream. This we find in the Blackstone River, into which is poured the sewage of Worcester.

ficance. The actual amount of material in the water which gives rise to this odor is extremely minute.

The pollution of ground waters is ordinarily a very much simpler problem for investigation. The filtration of waters through porous soils, if not too rapid, results, through the action of micro-organisms, in the complete mineralizing of the organic matter, — the conversion of the carbon into carbonic acid, the hydrogen into water, and the nitrogen into nitric acid. A ground water should, therefore, be quite colorless, and practically free from ammonia in any form. If the water has never contained any considerable amount of vegetable or animal nitrogenous matter, it will be low in nitrates; if, on the other hand, it was formerly polluted with animal matter, we must expect it to be high in nitrates. If we find in a ground water both nitrates and ammonia, the inference should be drawn that the purification from organic matter is incomplete. The presence of even a very small amount of organic matter in a well water is a matter for grave suspicion and anxiety. The usual source of contamination of a well is a cesspool near by, or the refuse thrown on the ground near a house, or the drainage from a stable or barn. The purifying power of a porous soil to convert this decaying matter into harmless mineral matter is very great, but it may be overtaxed. Suppose the well is lower than the house or barn, the soluble refuse matters then drain towards the well. It may happen in the course of time that excessive drainage will cause the upper layers of the soil to become sewage-soaked, and that the effective thickness of soil for purification will gradually become less and less until it is insufficient, and the well water which has been hitherto good becomes bad. Again, an unusually heavy or long-continued rain may wash the drainage matters through the soil so rapidly that there is not time enough to effect a complete purification before the water reaches the well. An impure well water is usually more to be feared than an impure pond water on account of the nearness of its sources of pollution.

To sum up in a word the lessons which the chemical examination of water teaches us: it is only by constant watchfulness over its condition, and of its possible sources of contamination, that we can feel sure of the fitness of a water for drinking.

shortest amount of time required to move the armature. The second function is to control the supply of compressed air which flows through the air-tight chamber referred to.

The pneumatic portion includes the air pump, the tank in which is stored the air under pressure of ten pounds, the air-tight chamber of the electro-pneumatic valve, the various diaphragm valves at the heat supplies, and the piping which connects the parts just enumerated.

The pneumatic chamber of the electro-pneumatic valve has three openings, all controlled by the magnet armature within the chamber. The first leads to the air supply or tank, the second to the diaphragm valves at the heat supplies, and the third is an escape for the air when the pressure is removed at the diaphragms.

The valves at the heat supplies are operated by rubber or metallic diaphragms, strengthened by wooden saucers and propelled by the compressed air which is controlled by the electro-pneumatic valve. When the compressed air is applied to a diaphragm, it closes the steam valve, damper or register, shutting off the heat. When the pressure is removed, the air escapes through the third opening in the air-tight chamber of the electro-pneumatic valve, allowing the diaphragm to return to its original and normal position, assisted by metallic springs provided for the purpose.

In case steam is used, three very desirable results are attained: 1st, both valves connected to a radiator are operated simultaneously, rendering it impossible to cut off one without the other, and the valves are left either fully opened or closed. 2nd, the stem of a valve does not turn, but moves with a piston-like motion, thus saving grinding at the seat, which occurs when the valve is turned by hand. The packing, for the same reason, will last longer. 3rd, when the valves have cut off the supply of steam no leakage can take place through them, when the metal cools off, because the pressure of the diaphragms will keep the valves tightly closed.

It is possible by means of this apparatus to keep the temperature of a building constant within two degrees.

The lecturer then gave a number of instances where this system had been applied and gave perfect satisfaction.

The illustration which we here present shows the thermostat electro-magnetic device and a steam value in operation so plainly

that no detailed description is necessary. *A* is the valve to be operated upon; *C* is the thermostat which makes at a remote point the electrical circuit which operates the electrically actuated secondary valve *B*, controlling the air under pressure operating on the valve *A*. The battery employed is represented at *D*. A pipe *E* leads from some convenient source of compressed air which is controlled by the valve *B* in such a manner that it will operate the valve *A*.

A large working model showing the manner of application to the different systems of heating was on exhibition, which was examined with considerable interest after the meeting was adjourned.

MEETING 374.

The Causes of the Recent Floods in Germany.

BY PROF. WM. H. NILES.

The Development of Bridge Building.

BY PROF. GEORGE F. SWAIN.

The 374th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, April 12th, at 8 P. M., Mr. H. M. Howe in the chair.

After the reading of the minutes of the previous meeting, the election of new members, and the transaction of some other business, the chairman introduced Prof. Wm. H. Niles, of the Institute, who spoke on "The Causes of the Recent Floods in Germany."

Prof. NILES first called attention to the fact that destructive floods had recently occurred in different portions of Europe. Severe storms and large accumulations of snow were to be recognized as primary causes of the inundations which had rendered the season a

it shall require a load five or six times as great as the actual load to break it down, or, as we say, with a factor of safety of five or six. It will at once be asked how we can possibly have bridge disasters if bridges are built to carry five or six times the loads actually put upon them. It might seem to show engineering science to be lamentably insufficient, but the fact is that it is extremely rare for a bridge to break down from faults of construction, and when one does, it is always from extreme faults of design or material which could easily have been avoided.

I shall endeavor tonight to present to you a very brief and necessarily incomplete account of the development of bridge building, which may render clear some points often misunderstood; and at the close I shall show you some illustrations of faults of design which will show the necessity of allowing this margin or factor of safety.

The first bridges of which we have any account were of stone, and these were built long before Christ, by the Egyptians, Assyrians, and Romans. They were for the most part arches, usually semicircular, or nearly so; and by the Romans the construction of stone bridges was brought to a high degree of perfection. At that time stone arches were used on a large scale principally in connection with works of water supply, although highway bridges were also built; and there was in Rome a bridge across the Tiber, with a span of eighty-four feet, and others of smaller dimensions. Rome was supplied with water through nine aqueducts, the first two of which were built under ground, so that, in case of invasion, the city should not be deprived of water. The third, however, was built partly above ground, and so strong that the two succeeding ones were built directly above it, so that they had in places three tiers of arches, one above the other, each carrying a conduit. Arches with more than one tier were also built where but one conduit was to be carried. For instance, the Pont du Gard, which carried across the river Gardon the aqueduct supplying the city of Nismes, had three tiers of arches, and this construction was probably adopted on account of the ease with which the conduit could be maintained and inspected. This bridge, built in the time of the Emperor Augustus, was 885 feet long on top, and 157 feet above the stream. The longest arch in the lower tier had a span of 80 feet 5 inches, while others had spans of 63 and 51 feet. The arches of the upper tier had all the same span, 15 feet 9 inches.

Stone arches, while expensive in first cost, have the great advantage of permanence. Many of the old Roman arches are standing today, and in good condition. A stone arch requires but little expense of maintenance, and is not liable to be outgrown as the weight of rolling stock increases, for the reason that the principle upon which the stone arch is built is essentially different from that governing the design of any other kind of structure. Other bridges are designed so as to be *strong* enough to carry given loads. If these loads are exceeded, the margin of safety is reduced. The question of stability has scarcely to be considered. A stone arch, on the contrary, is designed primarily so as to be *stable*, so that it will not tumble down, as an arch built of loose blocks may do. The question of strength must, of course, be considered; but, fortunately, if a stone arch is stable, it is almost always amply strong even for much larger loads than are generally to be put upon it. A stone arch, therefore, if once correctly designed so as to be stable, is not generally liable to be rendered dangerous even if the weight of rolling stock is doubled.

Wooden bridges first came into very extensive use on the railroads of this country; and, in fact, they have been used here more than anywhere else. One of the earliest types was the Town Lattice, patented in 1820, and built entirely of plank, joined together with oak treenails. Another early type was the Howe Truss, patented in 1840. This was the first truss in which iron and wood were combined, and it and the Town Lattice are still the standard wooden bridges. Among the early wooden bridges may be mentioned the Portage Viaduct, on the Erie Railroad, a wooden trestle bridge, about 230 feet high, which was entirely destroyed by fire, May 6, 1875. Another was the Cascade Bridge on the Erie Railroad, an arch with a span of 275 feet and a rise of 45 feet, probably the largest wooden arch ever built.

Wooden bridges may easily be made amply strong up to spans of 150 or 200 feet, and they have some advantages; but their first cost, for large spans, is not sufficiently less than that of an iron bridge, to make up for their shorter life, greater cost of maintenance, and the added danger from fire.

The earliest iron bridges were of cast iron. The first of these was commenced in 1755, in Lyons, and was intended to be three arches, each with a span of 25 meters. It was, however, not completed, the

wrought iron. But gradually wrought iron supplanted cast iron as a material for bridges, until, at the present day, the latter is not used at all, or only for unimportant parts, such as bed plates.

The first wrought-iron bridges were suspension bridges, of which a large number were built in Europe and America during the early years of this century. Then followed the use of simple beams or of rails rivetted together, spanning short openings, and gradually the modern truss bridge was developed, composed of separate bars united at their ends. In truss bridges it was for a long time very common to make simply the tension members of wrought iron, the compression members being either of wood (a method extensively used in America at one time) or of cast iron; and it is only within a comparatively few years that such so-called combination bridges have gone out of use, it being found better and more economical to make the entire bridge of one material,— wrought iron. Among the records of the patent offices, both in Europe and America, may be found innumerable examples of combination bridges, some of amazing complexity, and each possessing, in the opinion of its inventor, some virtue rendering it superior to all its competitors. An examination of these records will suffice to convince anybody that the progress in bridge building has been in the direction of simplicity; and one can only marvel that the mind of man could have conceived systems of framework and combinations of shapes and of material so intricate and so completely *incalculable*. As just stated, the early wrought-iron bridges, aside from suspension bridges, were simple beams, and from these grew the type of the plate girder, consisting of a vertical web or plate, stiffened at intervals by vertical pieces and with flanges at top and bottom. These plate girders were built of considerable size, especially in England, where engineers seemed loth to adopt the use of the framed truss. The Britannia Bridge is a striking example of the use of a plate girder under circumstances where it involved a very large waste of material. The bridge, completed in 1850, consists of two spans of 460 feet each, and two of 230 feet each. It is what is known as a tubular bridge, but is, in reality, nothing in principle but a huge plate girder, the two plate girders, one on each side of the roadway, being united at the top and bottom by one continuous flange, forming a closed tube. The waste of material alluded to arises largely from the fact that if the sides were simply thin plates

Another distinctive feature of American bridges is the use of the so-called trestle work. In France and Germany, when a deep and wide ravine has to be crossed, it is customary to use long spans resting on isolated piers. American engineers, however, prefer a trestle in which the spans are short and the piers light and close together. In considering the different types of bridges it is important to remember that ease of erection is a very important point to consider. European viaducts, consisting of long spans on isolated piers, have frequently been erected without the use of false works, by building the entire structure, several spans in all, complete, and rolling it out over the piers. The American system of trestle works may be erected with even greater ease, each span being built out from the preceding one, and the pier built up to it, with the aid of an overhanging traveler or crane. As a striking example of the modern American trestle, and as illustrating the rapidity with which such bridges may be constructed, the Kinzua Viaduct may be mentioned, in northwestern Pennsylvania. This bridge, 301 feet high, and 2053 feet long, was erected by 125 men within the space of four months.

A short description may now be given of some of the large bridges of recent years. Among arches, that at St. Louis, across the Mississippi River, is one of the most remarkable, and it was the first large arch of iron (steel) built in this country. It was completed in 1873, and carries a railroad below and a highway above, with three spans, the longest of 520 feet. Each span of this arch is composed of five parallel ribs, and each rib is built of two parallel tubes, 12 feet apart, 18 inches in outside diameter. These tubes are of crucible steel, in lengths of 12 feet, and connected by a system of webbing. The ends of the arch abut firmly against the masonry of the piers and abutments. Considerable difficulty was experienced in the erection of this structure. Of course, the use of false works or scaffolding in the river was out of the question, and some method had to be adopted by which the bridge could be built out from the piers and abutments. Wooden towers were erected on these piers and abutments, and, by means of cables running from these towers, each rib was built out simultaneously, piece by piece, from each end, until they met in the center of the span; but when they did meet it was found that they did not come together exactly, and that the center piece did not fit. The cables by which the arch was supported were adjusted in all

built precisely like an arch, except that it is turned upside down. As a beautiful example of a stiffened suspension bridge, the Point Bridge, across the Monongahela River, in Pittsburg, may be mentioned, with one span of 800 feet, two side spans of 145 feet, and a rise of 88 feet. This bridge was built in 1876, and is the only one of its kind in this country, so far as I am aware.

Arches are sometimes combined with suspension bridges, the object being that the outward thrust of the arch, at the abutments, shall be counterbalanced by the inward pull of the suspension cable, thus producing a simple vertical reaction. The best example of this type of bridge, which must not be confounded with the truss having upper and lower chords curved, is the bridge across the Elbe, at Hamburg, with spans of 307 feet.

Of all types of bridges for large spans cantilever bridges have of late years attracted the most attention. It is only within ten or fifteen years that these bridges have been built to any great extent, although the principle on which they are based is very old. An ordinary truss bridge is a frame supported at its two ends by vertical forces. A cantilever, on the contrary, may be supported at one end and at a point some distance from the other end; or at two points, each some distance from the ends. A cantilever, therefore, extends between two supports, and projects beyond them at one or both ends. The ordinary arrangement of a cantilever bridge of three spans is this: at each end a cantilever extends from the abutment out over the first pier into the central span; on the ends of these cantilevers a simple girder rests, just as it would upon piers. Of course the weight on this simple girder and on the projecting arms of the cantilever tends to tip the latter, and the abutment ends require, in many cases, to be anchored by long bolts running down into the masonry. Another arrangement of a cantilever bridge, for three spans, is to have one cantilever spanning the central opening, and projecting at each end beyond the piers into the side openings. There is, in this case, a simple girder at each end, resting on the abutment and on the projecting arm of the cantilever. In this case, therefore, there is one cantilever and two simple spans, while in the previous case there were two cantilevers and one simple span. While cantilever bridges are generally built for three spans, the same principle may be easily extended to any number of spans, as at the great bridge now being built across the Hudson, at Poughkeepsie.

and deep river, the erection of false works is frequently impracticable, and some means has to be adopted by which the bridge may be built out, piece by piece, over the openings, without intermediate support. We have seen how arches, such as those at St. Louis and at Oporto, have been built out from the piers, and how European bridges are sometimes rolled out over the piers. Now the cantilever permits, as is easily seen, of being built out, piece by piece, as soon as one span is erected. Frequently, in cantilever bridges of three spans, the side spans are built on false works, and then the center span built out from each end; or, in the case of long cantilevers, like that at Poughkeepsie, one or more of the central spans may be erected on false works, and the adjacent spans then built out. In the Kentucky River Bridge, as already stated, the existence of heavy anchorages rendered it only necessary to have the two temporary timber piers.

Since the date of the Kentucky River Bridge not fewer than six cantilevers have been built in this country, and the following may be specially mentioned: the Minnehaha Bridge, across the Mississippi, near St. Paul, is not a pure cantilever bridge. It consists of two cantilevers, united at the center of the middle span, with no simple girder between them. The Frazer River Bridge, on the Canadian Pacific Railroad, is a good example of a cantilever, and was soon followed by the great bridge across the Niagara River, just below the Falls. This bridge has a total length of about 910 feet, a central span of 470 feet, and the rail is 239 feet above the water. It was built in the remarkably short time of about eight months. The bridge over the St. John, at St. John, New Brunswick, built in 1884, has three spans, the central one of 447 feet. It has two cantilevers and a simple span in the middle, and was the first through cantilever bridge in America. At Lachine, in Canada, a so-called cantilever was built about a year ago, across the St. Lawrence River; but this is not really a cantilever bridge. The Kentucky and Indiana Bridge across the Ohio, at Louisville, is another fine example of a cantilever bridge; and the great Poughkeepsie Bridge, now in process of erection, with a total length of about 3100 feet, in seven spans, the largest 548 feet in length, will be the finest example in America of this class of structure.

In Europe cantilever bridges have also been built frequently within the past ten years, there being at present four or five in Germany.

MEETING 375.

*Precious Stones in the Last Decade.**

BY MR. GEORGE F. KUNZ.

The 375th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, April 26th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, the election of new members, and the transaction of some other business, the President introduced Mr. George F. Kunz, of New York, who read a paper on "Precious Stones in the Last Decade."

Mr. KUNZ said: The American spirit of unrest finds its outlet in an incessant desire for change and novelty. In this we are sharply distinguished from the Frenchman, Englishman, or German, who believes that a good thing once is a good thing always. For us a thing must not only have excellence, but it must also be new or unique to satisfy the demands of this American trait. So, of precious stones very few fail to escape the edicts of Dame Fashion, who is influenced largely by the demands of her American followers.

During the last decade new stones have come into favor, some neglected ones have regained their popularity, and still others have been shown out entirely, such as the amethyst and cameo. The latter, no matter how finely cut, would not now find purchasers at one fifth of their former value, for about ten years ago they were eagerly sought after at from four to twenty times present prices. Rubies were considered high ten years ago, and a furthur rise was not looked for, but today they are still higher, a $9\frac{1}{8}$ carat stone being quoted at $33,000. There is no demand at present for topaz, yet a syndicate of French capitalists has been organized to control the topaz mines of Spain, in the expectation that after twenty years of neglect this gem will again find favor in the sight of fashion. Coral has felt the change of fashion, for during the last three years

* For the fuller text and other references, see *North American Review*, July, 1888; Report of Department of Mining Statistics, 1888; *Science*, Vol. V, p. 399, Vol. VIII, p. 192, Vol. X, pp. 69, 168, 226, Vol. XI, p. 118; *Popular Science Monthly*, April, 1886, p. 824; *Amer. Asso. Advan. Science*, Vol. XXXIV, p. 250.

only in Siberia, and even there of poor quality. Though found in large crystals, a perfect gem of even one carat was a great rarity. Here, however, fine gems, rarely under four carats, were found, and an exceptional one weighing sixty-seven carats. They can be numbered among the most remarkable gems known. Strange to say, among this alexandrite variety a few have been found which combine the characteristics of the cat's-eye and the alexandrite, and were, in fact, the alexandrite cat's-eye.

Moonstones, also from this same province of Kandy, Ceylon, were brought to light by this search for cat's-eyes. It would not be an over-estimate to say that 100,000 of these stones have been mounted here in the last four years. They vary in size from one-eighth of an inch to nearly two inches long and one inch thick, and many of them surpass anything hitherto known of their kind in beauty and size. Those that display the *chatoyant* white and the hazy blue color are especially beautiful.

The demand for the cat's-eye also brought into notice the then rare mineral from Asbestus Mountain, forty miles north of the Vaal River, South Africa, known as crocidolite, more especially that variety that has been altered to a quartz cat's-eye. In this stone an infiltration of siliceous material coated each fiber with quartz or chalcedony, giving it the hardness of seven. This pleasing stone sold readily for six dollars a carat, and at the outset even more; but owing to the excessive competition of two rival dealers, who sent whole cargoes of it to the London market, the price fell to one dollar, or even to twenty-five cents, per pound by the quantity. Even table tops have been made of this material by veneering. Vases, cane heads, paper weights, seals, charms, etc., were made of it, and sold in large quantities. Burning it produced a bronze-like luster, and by dissolving out the brown oxide-of-iron coloring an almost white substance was obtained, which was dyed by allowing it to absorb red, green, and brown-colored solutions. These, owing to the delicacy of the fibers, were evenly absorbed.

Ten years ago this material was practically unknown; but so extensively has it been sold that, today, it is to be found on every tourists' stand, whether on the Rigi, on Pike's Peak, in Florida, at Los Angeles, or at Nijni Novgorod, showing how thoroughly organized is the system of distribution in the gem market. Missionaries have never spread a religion half so rapidly as traders have disseminated the cat's-eye.

Never have pearls been more popular or commanded such high prices as during the past ten years. At present nothing is considered in better taste than the pearl, on account of its purity and subdued beauty. This unusual demand has had the effect of greatly stimulating the search for them, especially on the west coast of Australia, the Thursday Island, the Sooloo Archipelago, in Ceylon and the Persian Gulf, and also along the coast of Lower California.

The demand embraced pearls of all colors except the inferior yellow. The fine black pearls from Lower California have been in great request, single ones bringing as much as $8000. With these black pearls are found many beautiful gray and grayish-brown pearls. The different fisheries of the world produce fully $1,000,000 annually, of which our California fisheries produce probably one sixth. Kentucky, Tennessee, and Texas have given us over $10,000 worth of pearls per annum. Their remarkable fresh-water pearls, especially the pink ones, are unrivaled for delicacy of tint. But within the last five years many of the fancy-colored pearls have received their variety of color not from nature but from artificial means.

In 1882 a very remarkable discovery of sapphire was made in the Zenskar range of the northwestern Kashmur Himalaya, near the line of perpetual snow, a short distance from the village of Machel, and one-half day's journey from the top of Umasi Pass. The stones were found at the foot of a precipice, where a land slide had taken place, the including rock being gneiss and mica.

At first they were collected by the villagers, who were attracted merely by the beautiful colors; and so little was their value realized that they were used as flints for striking lights with steel. So abundant were they at first that one writer speaks of having seen about a hundred weight of them in the possession of a single native. Several crystals were found weighing from one hundred to five hundred carats each.

[The lecturer next spoke of the Burmese ruby mines, then of the diamond mines of India, Borneo, Australia, and South Africa, giving a detailed account, illustrated by different lantern views, of the ancient and modern methods of working the diamond mines. He stated that the yield of the mines of India, Borneo, and Australia was not over one per cent, and that of the Brazilian mines was only about nine per cent, of the total yield. The yield of the South Afri-

minerals were identical with the South African, the pyrope garnet, ilminite, biotite, and pyroxine among others being present, yet, by an analysis of the enclosed carbonaceous shales from which it is believed that the diamond is formed, it was found that the Kentucky shale contained only .681 of carbon, while the South African contained 35 per cent, and could be readily ignited with a match. Hence, unless the peridotite has penetrated the older and richer Devonian shales, the probability of finding diamonds there has been considerably weakened by the investigation.

A beautiful twinned hexoctahedral diamond crystal of 4⅓ carats was found at Dysartville, N. C., in June, 1885, and sent to me for examination. On visiting the locality I authenticated all the facts of the finding. A boy had discovered the "pretty trick," as he called it, at a spring, and it was some time before the rural folk suspected that it was a diamond. None of the associations of the diamond were observed at the spring, therefore it is probable that the stone was carried to the spring by some miner who was washing up his gold, and failed to notice the shining crystal among the "wash-up." The crystal is not pure white, having a faint grayish-green tint, although it is quite perfect as a gem, and would make, when cut, a stone worth about $100. A number of stones called diamonds have been found at Brackettstown, near by, but they have proved on examination to be transparent zircon or smoky quartz.

[Mr. Kunz here gave an account of numerous large diamonds; also of many notable collections of precious stones. He next spoke of the investigations which have been made, which leave but little doubt that microscopic diamonds have been found in meteorites.]

The handsomest and lowest-priced of our ornamental stones, and one which has been introduced most extensively, is the so-called Mexican onyx, or Tecalli, as it was first called from the town of that name in the State of Puebla, Mexico, where it is found. The deep colors are richer than those of any marble known, and its wavy, stalagmitic structure, and the high polish it admits of, have made it popular throughout the whole civilized world. With a metal mounting the effect is greatly enhanced. It occurs in almost unlimited quantities, and fully $500,000 worth has been used in the United States for marble tops, mantels, vases, etc.

The existence in Arizona of deposits of agatized and jasperized

of Mexican onyx of the same size with the same power, fifty sections of marble, and ten of granite. Still, in spite of its excessive hardness, this is destined to become one of our richest American ornamental stones. It is already used for mantels, table tops, tiling, paper weights, inkstands, as well as for an endless variety of charms and other objects similar to those made from onyx.

The turquoise, long known as occurring at Los Cerillos, New Mexico, was known to the natives before the arrival of the Spaniards, who also mined them for a time. It is now cut by the natives into flat beads or other ornaments, which are sold as charms along the lines of the railroads. The mines have been worked to some extent. The color is not fine, but these green stones have been artificially stained to a fair blue, and many of them have been sold as fine turquoises. Suspecting that the color was not genuine, I tested it with ammonia, and found that it dissolved readily in a moment, whereas the color of the Persian, or even of the Egyptian turquoise, is unaffected if the stone is left in ammonia for twenty-four hours. Prof. William P. Blake describes a new locality of the turquoise at Turquoise Mountain, an outlying spur of the Dragoon Mountains, now called Turquesa, twenty miles from Tombstone, in Cochise County, Arizona. The color, he stated, is apple and pea green, exactly like that of the New Mexican stone. This deposit had evidently been worked as early as the New Mexican, since there were large piles of débris around the ancient excavations, which were probably made before the country was inhabited by the Apaches. These turquoises, like those of the New Mexican locality, have little commercial value.

Prof. F. W. Clarke and Mr. J. S. Diller, of the United States Geological Survey, have made an exhaustive study, both chemically and microscopically, of the New Mexican turquoise, as well as the trachyte in which it occurs, and found that, with the exception of the very dark-green variety, the series of analyses agreed with the analyses of the Persian turquoise and the Californian turquoise, replacing apatite or phosphate of lime, in each case the base standing to the acid very slightly in excess of two to one. This excess was accounted for upon the supposition that it is represented by a fair admixture of iron, and that possibly it all represents an alteration from apatite. It is of interest to note that V. von Zepharovitch and G. E. Moore described and analyzed a turquoise from Taylor's Ranch, Presno County, California, which here replaced crystals of apatite.

This stone is identical with one brought from China, several centuries ago, and described by De Boot, De Laet, Boyle, and others, as the *oculus mundi*, or world's eye, and of the *lapis mutabilis*, which, when wet, became entirely transparent, except a central nucleus (possibly a core of chalcedony) that still remained white. If the central core was black, the stone was called *oculus beli*.

In 1883 topaz was first discovered in Colorado, and since then it has been found in some abundance at Platte Mountain, Cheyenne, and at Crystal Peak, near Pike's Peak. Many of the crystals are remarkable for their size, several of them weighing over a pound each. The smaller ones are transparent, and range in color from pellucid white to rich cinnamon brown; some few are light blue and light green. The two largest weighed 125 and 198 carats respectively, and equaled those from any known locality; but $3000 would probably be a fair estimate of the value of all that have been found there.

At Stoneham, Me., while examining a series of minerals which had been collected by N. H. Perry, I identified topaz; and, after considerable blasting, many interesting minerals were found, and among them a few crystals of this mineral measuring one foot on a face. There were a number of smaller ones, some of which had small transparent spots that afforded a limited number of gems of several carats each.

Five years ago the existence of rock crystal of any size was almost unknown in the United States; but about that time a large, clear mass, weighing thirteen pounds, which had been found in Alaska, was brought to New York city and made into thin slabs for hand mirrors. In 1885 a fifty-one pound fragment, said to have been broken from a crystal which originally weighed five hundred pounds, was found in Chestnut Hill Township, Ashe County, N. C. On visiting the locality I found that most of the crystals in that locality were obtained either by digging where one crystal had been found, or by driving a plow until it unearthed them. Several dozen crystals in all have been found here, one mass of thirty pounds being almost absolutely pure. Some of them would afford larger masses of clearer rock crystal than has before been obtained at any American locality. It is of use for crystal balls, clock cases, hand mirrors, and similar objects.

interesting one. The color of the iron and magnesian varieties depends on the amount of iron present. It ranges from the colorless De Kalb through all the shades of brown to the Pierrepont black, while the lithia tourmaline, containing more or less manganese, gives us the red, green, and blue as well as the colorless varieties. The shades of color do not depend on the absolute amount of manganese present, but rather on the ratios existing between that element and the iron. Thus when the amount of manganese and iron are equal, we have the colorless, pink, or very pale green tourmaline. An excess of manganese produces the red varieties; and if the iron is in excess, the various shades of green and blue are the result.

The subject of artificial gems is at the present moment of considerable interest, not only commercially, but also as furnishing an example of the surprises the modern science of chemistry is constantly giving us. In the spring of 1886 the syndicate of dealers in diamonds and precious stones, of Paris, were informed that certain stones, which had been put upon the market by a Geneva house and sold as rubies from a new locality, were suspected to be of artificial origin. It was surmised that they were obtained by the fusion of large numbers of small rubies, worth at the most a few dollars a carat, into one fine gem, worth from $1000 to $3000 a carat.

Some of these artificial stones were kindly procured for me by Messrs. Tiffany & Co. I was not, however, permitted to break them for analysis, to observe the cleavage, or to have them cut so that I could observe the optical axes more correctly; but I could have detected the artificial nature of these productions with a pocket lens, as their whole structure is that peculiar to fused masses. Examination elicited the following facts: the principal distinguishing characteristic between these and genuine stones is the presence in these of large numbers of spherical bubbles, rarely pear-shaped, sometimes containing stringy portions, showing how the bubbles had moved. These bubbles all have rounded ends, and present the same appearance as those seen in glass or other fused mixtures. They are nearly always in wavy groups or cloudy masses. When examined individually they always seem to be filled with gas or air, and often form part of a cloud, the rest having the waviness of a fused mixture. Some few were observed inclosing inner bubbles, apparently a double cavity, but empty. In natural rubies the cavities are always angular or

decrease the density. As a test, this is too delicate for jewelers' use, for if a true ruby were not entirely clean, or if a few of the bubbles that sometime settle on gems in taking the specific gravity were allowed to remain undisturbed, it would have about the same specific gravity as one of these artificial stones.

I found, on examination by the dichroscope, that the ordinary image was cardinal red, and the extraordinary image a salmon red, as in the true ruby of the same color. Under the polariscope, what I believe to be annular rings were observed. With the spectroscope the red ruby line, similar to that in the true gem, is distinguishable, although perhaps a little nearer the dark end of the spectrum.

The color of all the stones examined was good, but not one was as brilliant as a very fine ruby. The *cabochons* were all duller than those of fine, true stones, though better than poor ones. They did not differ much in color, however, and were evidently made by one exact process or at one time. Their dull appearance is evidently due in part to the bubbles. The optical properties of these stones show that they are individual, or parts of individual, crystals, and not agglomerations of crystals or groups fused by heating.

In my opinion, these artificial rubies are produced by a process somewhat similar to that described by Frémy and Feil,* by fusing an aluminate of lead in connection with silica, in a siliceous crucible, the silica uniting with the lead to form a lead glass, and liberating the alumina, which crystallizes out in the form of corundum, in hexagonal plates, with a specific gravity of 4.0 to 4.1, and the hardness and color of the natural ruby, the latter being produced by the addition of some chromium salt. By this method rubies were formed that, like the true gem, were decolorized temporarily by heating.

It is not probable that these two stones were formed by Gaudin's method,† by exposing amorphous alumina to the flame of the oxyhydrogen blow-pipe, and thus fusing it to a limpid fluid, which, when cooled, had the hardness of corundum, but only the specific gravity 3.45, much below that of these stones. Nor is it at all likely that they are produced by fusing a large number of natural rubies or corundum of small size, because by this process the specific gravity is lowered to that of Gaudin's product. The same also holds good of quartz, beryl, etc.

* *Comptes Rendus*, 1887, p. 1039. † *Comptes Rendus*, t. XIX., p. 1842.

Paris, the successful result of a second series of experiments to produce artificial rubies. By the former process the rubies were defective, but by the new process rubies one to two millimetres in size were produced, having the purity of the natural gem, and, like it, scratching topaz. M. Frémy's method was to fuse fluoride of borax and aluminum containing bichromate of potash. When under the continuous action of fire for fifty hours a porous and friable gangue was formed in the crucible. In this gangue the rubies appeared, and were separated from it by means of washing. M. Frémy reassures the jewelers by declaring that his discovery is of purely scientific interest, and will have no bearing on the trade in precious stones.

In *Nature*,* Mr. MacTear, of the St. Rollox Works, Glasgow, published some investigations by which he claimed he had produced artificial diamonds. Prof. N. S. Maskelyne found this claim to be unfounded; and this has been the case with other investigators, such as Cagniad de Latour and J. H. Gaunall, H. Depretz, Dr. Hare, Prof. Silliman, and M. de Chauconstois. In 1880 Mr. J. Ballantine Hannay read before the Royal Society a paper in which he claimed to have produced artificial diamonds after eighty dangerous experiments. He had obtained the results, he said, by tightly sealing in steel and iron tubes or coils, about four inches thick, some made by boring out a solid block of iron, containing 10 per cent bone oil and 90 per cent paraffine spirit, and subjecting these tubes to intense heat for some hours. After eighty experiments he produced fourteen milligrammes of residue, a part of which he called diamond. The substance exhibited to the Society was undoubtedly diamond, being pronounced such by Profs. Maskelyne, Roscoe, Stokes, and others. But none of it can be seen today in the British Museum cabinet; and as the specimens were of a fragmentary character, and not crystals, it is believed by many that although they were diamonds, they were never made by Mr. Hannay.

The four volumes on mining statistics, published by the Geological Survey, and edited first by Mr. Albert Williams, and now by Dr. David T. Day, contains an annual report on precious stones in the United States which has done much to awaken a wide-spread interest in this subject.

* Vol. XXI., January 1, 1880, p. 203.

Let us consider for a moment some simple cases of induction. A coil of wire lying in a horizontal plane is threaded by the lines of force of the magnetic field of the earth. Let it be turned to the vertical, and all these lines are discarded. While the wires of the coil are cutting across the lines of force an electromotive force is set up in the coil, which depends for its value upon two things, — the number of turns of wire in the coil and the rate at which lines are discarded from its area. The latter depends upon the rate of motion, the area of the coil, and the frequency of the lines. It is plain to see that, as the coil first leaves the horizontal plane, the rate of cutting is rather slow, and the E. M. F. set up is, therefore, feeble. The rate of cutting, however, increases, at first rapidly, and finally more slowly, until at the vertical the maximum rate is reached and the highest E. M. F. developed. Continuing the rotation, the E. M. F. falls, becomes zero when the coil reaches the horizontal, and goes through the same changes of value with the opposite sign, as the rotation continues through the other half of the revolution. It is plain to be seen, without any abstruse investigation, that the curve of sines must at least very nearly represent the changes of E. M. F.

A coil of wire carrying a current is a source of magnetic lines. Let such a coil be approached to another, and the lines of the first pass through the second coil, developing in it a temporary E. M. F., as though it were turned over in a magnetic field. Let the first coil be laid upon the second and then its circuit broken. The lines of force that did thread through both coils disappear, and an E. M. F. is developed as though the lines had been discarded by the rotation of the coil. When the circuit is closed the lines of force are gathered in again, and an E. M. F., opposite in direction to that before obtained, is developed. This is all well known to you, but it is well to think it over, and think out the curves that will represent the changes. Consider what takes place when we close the circuit. We know a current does not instantly start at its maximum value, but for an appreciable time is an increasing current: the law of increase must be something like the curve *ab*, Fig. 1. The rate of gathering in of lines of force must be represented by

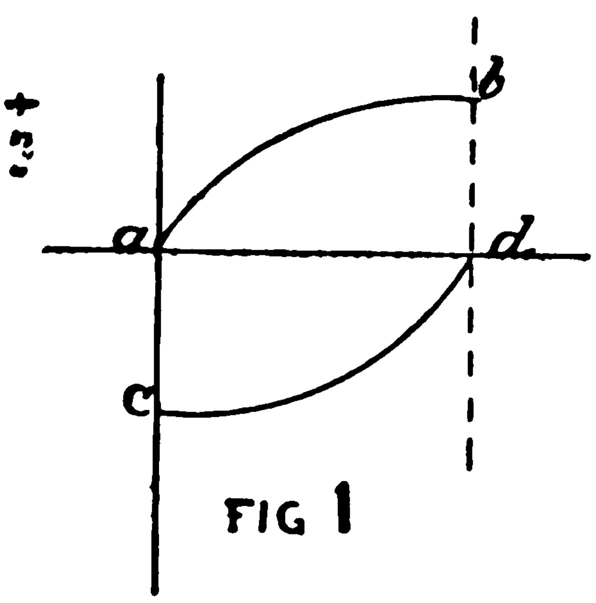


FIG 1

Let OA, Fig. 3, revolve about the center O, A describing the circle. Its projections on the vertical will evidently give the ordinates of the

FIG. 3

full line curve. In like manner OA' behind OA, by a quarter revolution, determines the ordinates of the broken curve. It is easy to show that OA'', the resultant of OA and OA', by the principle of the parallelogram of forces, will determine the ordinates of the resultant curve. In short, if OA and OA' represents two E. M. Fs. in magnitude and phase, OA'', the diagonal of the parallelogram, of which OA and OA' are sides, represents their resultant in magnitude and phase. Both the curves and the parallelogram construction show the resultant as differing in phase from each of the components by one-eighth of a period, being behind the first and in advance of the second.

Take now the case of a coil of wire to which is applied an alternating E. M. F. It has been seen that the alternating current in the coil produces an induced E. M. F. This must be combined with the impressed E. M. F. to obtain the resultant which determines the current. We are now prepared to determine the relation of these three quantities. Suppose we know from the heating effect, or otherwise, what current flows through the coil. Knowing the resistance, we know also the *effective* E. M. F. required to maintain that current.

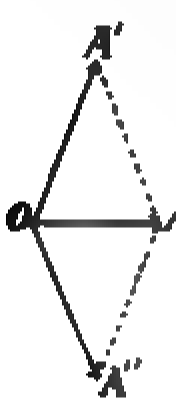


FIG. 4.

Let OA'', Fig. 4, represent this in magnitude and phase, OA', a quarter revolution behind the current line, is the line of induced E. M. F. Draw $A''A$ parallel to OA', make OA represent the magnitude of the impressed E. M. F., and complete the parallelogram. OA, OA', and OA'' represent the relations of the two components and their resultant. It is seen that the induced E. M. F. is nearly opposite the impressed, and that the effective E. M. F. is but a small fraction of either. It is well to

curve of products, and represents the mean power of the machine during one period. Now, a very interesting and important principle is this, that this mean product is half the product of OA'' by the projection of $`OA$ upon the line of current. This furnishes a very simple and beautiful method of comparing powers due to the different component electromotive forces, for, since there is only one current, the powers of the several E. M. Fs. are directly proportional to their projections on the line of current. If the projection is opposed to the current, the power due to that E. M. F. is negative, and the current is doing work. If the projection is in the direction of the current, the power is positive and that E. M. F. is doing work to maintain the current. I shall have occasion presently to apply this to the study of the action of motors. But first I wish to call attention to one more condition that influences induction. I have spoken of this coil of wire as producing a magnetic field, and thereby setting up a wave of counter E. M. F. which lags behind the wave of current by a quarter period, and, therefore, neither absorbs nor produces power. I put inside the coil a mass of iron; the magnetic field and counter E. M. F. are greatly increased, and an investigation shows that the wave of magnetization no longer coincides with the wave of current, but lags behind it by an amount which depends on several factors, such as the quality of the iron, the degree of magnetization, etc., and the wave of counter E. M. F., which must be a quarter period behind the wave of magnetization is more than a quarter period behind the wave of current. Let us apply the graphical construction to this case. Let this line OA, Fig. 6, represent the current. If the resistance be one ohm it also represents the effective E. M. F. OM may represent the magnetization through the iron. OB, at right angles to OM, now represents the counter E. M. F., and completing the parallelogram by drawing BA, AC, and OC, OC represents the impressed E. M. F. The diagram discloses a very interesting fact. The projection of OB on the line of OA is OD opposite in direction to OA. *The current, therefore, does work against the E. M. F. OB.* This work is due to the magnetization of the iron, and appears as heat in its mass.

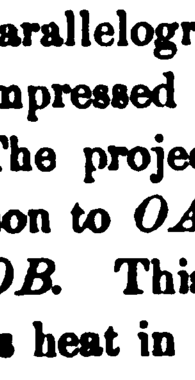


FIG 6.

To apply this to the study of alternating current motors, take the simplest case of two identical machines, one for a generator and the

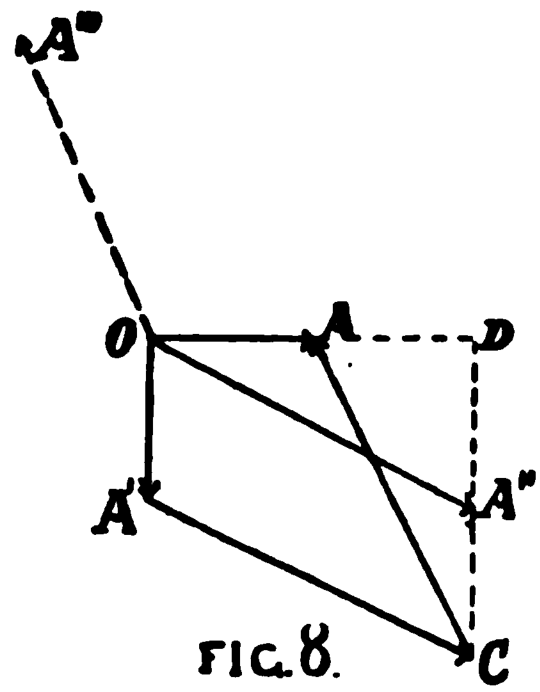


FIG. 8.

in determining the resultant. Let OA, Fig. 8, represent the resultant. Assume the rotation counter-clockwise, and leave out of account the retarding effect of the iron core, the E. M. F. of self-induction will be represented by a line 90° behind. Other things being equal, its magnitude varies with the current, and we may assume OA' to represent it for this particular case. The lines representing the E. M. F. of the generator, and the counter E. M. F. of the motor, must complete a polygon, and since they are equal they must be represented by two lines, such as $A'C$ and CA, or laying them off from O by OA'' and OA'''. Now, the projection of CA is opposed to the current, the current is doing work against it; CA is a counter E. M. F., and the machine to which it corresponds is a motor whose power is represented by the half product of OA by DA. If the load on the motor decrease, CA will approach opposition to $A'C$, A and A' approach O, the current represented by OA is diminished, and with it the power of the motor and the energy expended by the generator. This seems to me to be an example of an alternating current motor, which may be made as efficient as a continuous current motor under varying loads.

Here, however, is a case of a motor in which the relations are very different. CA, Fig. 9, represents the counter E. M. F. of the motor, and $\frac{OA \times DA}{2}$ its power. When the load on the motor diminishes, C moves to the left, diminishing AD, and so diminishing the product. But it will be seen that to maintain the necessary relation between the several quantities, OA, and, therefore, the current must increase, and more energy is consumed in heating the conductors when the motor is running light than when it is under load. But, although machines proportioned to give electromotive forces having the relations I at first indi-

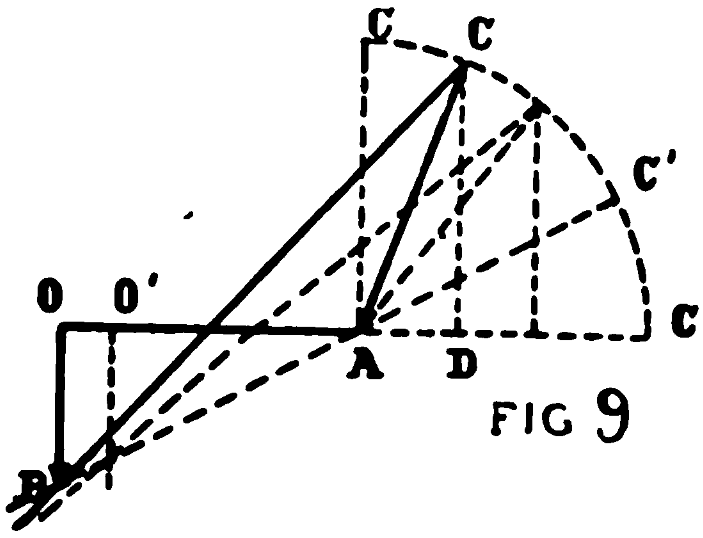


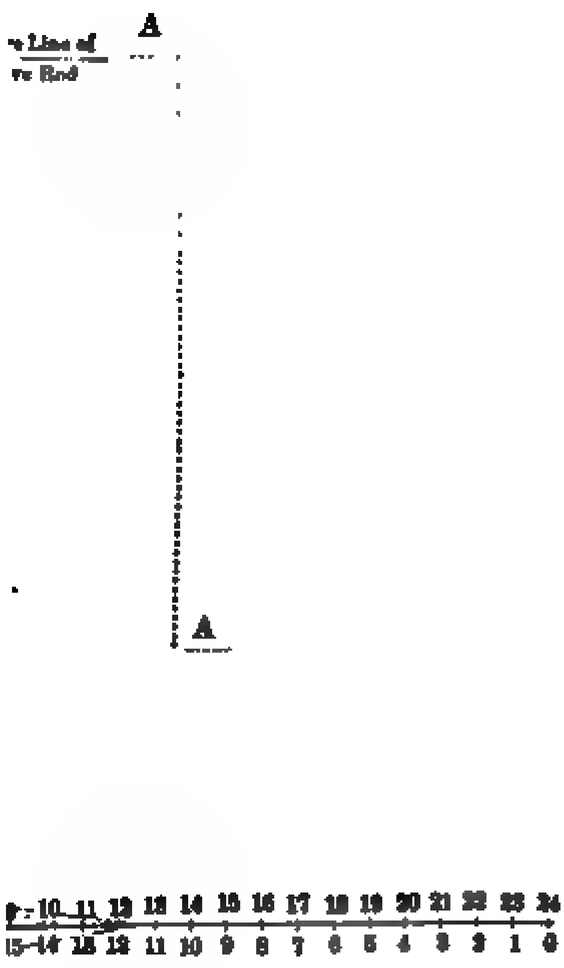
FIG 9

duced at *A* and *C*, and south poles at *B* and *D*, and that *C* and *D* are increasing while *A* and *B* are diminishing. When *C* and *D* reach a maximum, *A* and *B* are zero. Then *C* and *D* diminish and *A* and *B* increase with reversed polarity. The effect of this is that resultant poles travel around the ring in the direction *A C B D*. Practically, it is a rotating magnetic field without mechanical motion. If now we put inside the ring a cylinder of iron, free to rotate on an axis coincident with the axis of the ring, the iron will begin to revolve, and will tend to reach a speed equal to that of the field rotating around it. To understand the rotation it must be borne in mind that in all iron there is a certain "coercive force" that opposes magnetic change within it. In consequence of this the magnetism induced in the iron by the rotating field lags behind the field, and the iron is dragged along, as it were, by a magnetic friction. If the iron were absolutely soft and free from coercive force, it would not rotate. If it were so hard that magnetism once induced in it was permanently fixed, it would not rotate unless the rotation of the field were very slow. To produce good results the iron must, therefore, be neither too soft nor too hard. But we can do better than to try to obtain iron of a given degree of hardness: we may use the softest iron and wind upon it coils of wire, forming closed circuits. The currents induced in these coils, as the field revolves, have an effect similar to that of the hardness of the iron in causing a lagging of the induced magnetism in the core, and the latter is, therefore, dragged along by the rotating field.

The motor which I have here on the table has such an armature as I have just described. Mr. Tesla very kindly loaned it to me for this occasion, and I am glad to be able to give you a practical demonstration of the operation of motors as I have described. [The motor was then shown in operation.] Remember that the wire on this armature forms closed circuits. It has no communication with the wires outside. These connect to the stationary field coils. There is no commutator, no sliding contact even. There is nothing about the machine to require attention, except the bearings. Bearing all this in mind, I think the result you have seen is sufficiently remarkable.

The meeting closed with a vote of thanks to the speaker for his very interesting and instructive lecture.

Plate III.


A
A
9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
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SECTION THROUGH CENTRE.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

ABSTRACT OF THE

Proceedings of the Society of Arts,

WITH LIST OF OFFICERS AND MEMBERS,

FOR THE TWENTY-SEVENTH YEAR.

1888–1889.

MEETINGS 377 TO 391 INCLUSIVE.

BOSTON:
W. J. SCHOFIELD, PRINTER, 105 SUMMER STREET.
1889.

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CONTENTS.

PROCEEDINGS OF THE SOCIETY OF ARTS

FOR THE TWENTY-SEVENTH YEAR.

MEETING 377.

Heating Passenger Cars by Steam from the Locomotive.

BY PROF. GAETANO LANZA.

The 377th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, October 11th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, the President introduced Prof. Gaetano Lanza, of the Institute, who read a paper on "Heating Passenger Cars by Steam from the Locomotive."

Prof. LANZA first stated that the substance of his paper was taken from his recent report to the Railroad Commissioners of this State. He then said: While the railroad companies in this State are nominally using, as a rule, some one or more of the so-called systems, they have in many cases been trying the different appliances, more or less regardless of the systems, and the subject will be treated in this paper from the latter point of view, the different methods for accomplishing any one special object being discussed together, and not as forming a part of a certain so-called system.

We may, therefore, classify the subjects to be considered as follows: —

1. The means of coupling the steam pipes of the cars together.
2. The means of reducing the locomotive pressure before it reaches the train.
3. The means of disposing of the condensation.
4. The proper piping in the cars to give the necessary radiating surface, and freedom of circulation.

to break. Moreover, it does not seem probable that a metallic joint can be kept as tight as a gasket, unless it be more carefully handled than it is likely to be in the regular service of a railroad.

In conclusion, it is very important that all those roads that are at all likely to interchange cars should adopt the same coupling, even though they have nothing else alike.

The following considerations favor the adoption of the Westinghouse air-brake coupling: —

The train hands are all familiar with its management.

The patent expires shortly, and the payment of royalty would be avoided.

The three-quarter inch coupling, now used for the air-brake, would doubtless be too small, and it would be necessary to adopt the one and one half inch coupling. Also, it would be necessary to have the gaskets made of hard rubber or of some similar compound, and not of soft rubber. The Boston and Albany and the New York and New England railroads have already tried the Westinghouse couplings, and they work well.

REDUCING VALVES.

In regard to the means for reducing the pressure of the steam before it reaches the train, the most primitive way is to introduce into the pipe leading to the train an ordinary globe valve, and to require the engineer to regulate it by hand, so as to produce the proper pressure on the train. Some do this from choice, and others because they have been unable to find a reducing valve that did not get out of order. Some of those who use a globe valve add a safety valve, which blows off at a certain pressure, and thus warns the engineer that the globe valve wants attention. Nevertheless, the proper way to accomplish the object is to introduce into the pipe a reducing valve, which, when once set, will keep the pressure on the train uniform without the necessity of constant adjustment by the engineer.

There are many reducing valves in the market, but when they are subjected to high pressures, and not handled with more than ordinary care, they too often fail. This failure is often due to their extreme delicacy, and to the difficulty in keeping lubricated certain parts which are exposed to very high temperatures and require specially good lubrication. These valves generally have some kind

there is difficulty when cars have to be left for long periods in the cold with no heat supply. By the Martin, the Emerson, and several other systems, each car is drained separately.

In the Sewall system the steam passes from the main pipe into a valve in the middle of the car. If this valve is wide open the whole, and if partly open a part, of the steam passes through the car back to the main pipe, from which the condensation may be drained off by a trap or by the globe valve if it is open wide enough. If the trap or valve is closed the whole of the condensation is forced back into the rear car, and from the end of the main pipe of the rear car it is blown out. This is the method most commonly used on the Old Colony and the Fitchburg railroads during the run, both of these roads using the new style Sewall valve. If the valve or trap is partially open a part is disposed of in each way. When the old style valve is used they are more likely to depend upon the trap to drain the entire condensation of the car. When the condensation is all forced back, and globe valves are used instead of traps, it is customary to make use of the valves only on two occasions: —

(*a*). On heating up, to drain the condensation when the steam first starts through the car.

(*b*). On putting the cars away, to drain the main pipe thoroughly, so as to avoid all danger of freezing. For these purposes the globe valve works much better than the trap, as the latter does not furnish a sufficiently free exit for the steam, and freezing ensues when the cars are exposed without heat. There is an increasing tendency with those who use the Sewall system to discard the Sewall trap and use a plain globe valve. This is done on the Fitchburg and on the Old Colony roads.

The idea at the basis of most of the traps, whether those used to drain the main pipe or the car, is that the contraction and the expansion of some expansible metal or liquid, due to different degrees of temperature, shall respectively open and close the valve,— thus opening to let out the water, but closing to keep in the steam. This is effected by causing the trap to close at a certain fixed temperature, which, if the steam in the car were at atmospheric pressure, would be 212 degrees Fahrenheit.

The operation of the trap is supposed to be as follows: While the pipes are full of steam, so that the expansible metal is exposed

as condensation has taken place, sufficient to seal the entrance to the small pipe, the steam in the upper tank is separated from the other. Then, on cooling, the pressure decreases and the excess of pressure in the lower tank sends the water up into the upper tank. The original idea of putting the tank under the car was to make it serve as an auxiliary boiler, but Mr. Houston, recognizing the objections to having a tank under the car, is now fitting up a large number of cars with a similar device, where, however, there is no auxiliary boiler, and where, in place of the lower tank, there is a small box or trap just below the upper floor, from which proceeds the small pipe, and the upper tank is not set on the floor, but somewhat higher up. The effect of this is that the condensation water is collected in this upper tank, and thus it is in no danger of freezing, and also it gives out some heat through the walls of the tank into the car. It also furnishes hot water for cleaning up. When the car is set off, a sufficient number of valves are opened wide, and the water is all drained off.

No system of draining off the condensation water can be efficient without the means of properly venting the pipes and letting in air.

MAIN PIPE; RADIATING PIPES AND VALVES.

It seems to be most common to use one and one-half inch pipe for the main pipe. Some have used one and one-fourth inch, but one and one-half inch is more common, and gives better satisfaction generally. As to the location of this pipe, it is most frequently placed under the middle of the car, wrapped, of course, in hair, felt, or some other non-conducting covering. A better way is to place it between the sills and box it in. In this case it is also wrapped, and the surrounding woodwork should be protected by tin or sheet iron. Another and a better way yet is to place it inside the car on one or both sides. In this case it is not wrapped, but forms part of the radiating surface. The chief objection to this last arrangement is that the heat cannot be entirely shut off from one car without shutting it off from all the cars behind it. Another objection is that the passages are a little more crooked, but this is more than counterbalanced by gain in heating power.

On account of the exposed conditions of the car the radiating surface should be considerably more than would be required in a

Such a system works all right if proper care is taken of it, but it is desirable to reduce the number of valves needing attention, and also the danger of leakage by the use of some more complicated single valve, which can perform the necessary service, and at the same time be more free from liability to leak. In choosing between the different devices, the amount of the reduction of pressure of steam in its passage through the train is therefore a most important consideration, and this should be as small as possible.

A train should be heated without having high pressure steam on any car, for if, in order to get sufficient heat into the rear car, it is necessary to have a very high pressure in the first car, in that car there will be the danger of an explosion or of blowing off an end. This consideration also enforces the importance of freedom from resistance. The above is also a reason why a good and reliable reducing valve is a desideratum.

EXHAUST STEAM, LIVE STEAM OR WATER.

The main difficulty with any system of heating by means of water stored in a reservoir, and heated up by steam outside or inside of it, is the length of time required to heat up the cars in cold weather, because while the steam is heating the water it cannot be heating the car to the same extent as it would if not required to heat the water. A hot-water circulation seems to be better adapted either to heating in moderate weather, or else in cases where individual heaters, like the Baker or Johnson heater, are used and fire is kept in them nearly all the time.

Exhaust steam is very much needed in the locomotive to generate the draught, and it is certainly a serious question whether any of it can be spared to heat the train.

Any system which attempts to heat with exhaust steam is liable either to cause back pressure on the cylinder, or else to spoil the draught. Either of these results is very detrimental to the running of the locomotive. Mr. Houston, of the Atchison, Topeka, and Santa Fe Railroad, has used a system utilizing exhaust steam, which is open to the above objections to a slight degree only, if at all. The steam is taken from a point about half way down the exhaust nozzle by a pipe, and enters the pipe in the direction of its flow, thus utilizing its velocity to send it into the train pipe. A series of check valves retain the maximum pressure in the train.

them, it will be necessary at all the principal stations, and, perhaps, at all the stations where cars are left, that there should be either a stationary boiler, or else one or more locomotives specially devoted to heating cars, and that pipes or hose should lead from the boiler to those points where cars will stand when they are to be heated. For this purpose an ordinary low-pressure boiler would be sufficient, and it could also be used to heat the station.

This method is adopted by the Boston and Albany at Boston and Springfield, and by the Connecticut River at Springfield. It would certainly be the method to be adopted by most roads at all stations where they have occasion to leave cars in the cold for any length of time. Some roads, especially the Old Colony, are, however, obliged to leave cars at so many stations that it would be at least a hardship to be obliged to have a stationary boiler at each one of them.

It is an open question whether there is any other feasible means of heating up cars at the smaller stations where only two or three cars are left.

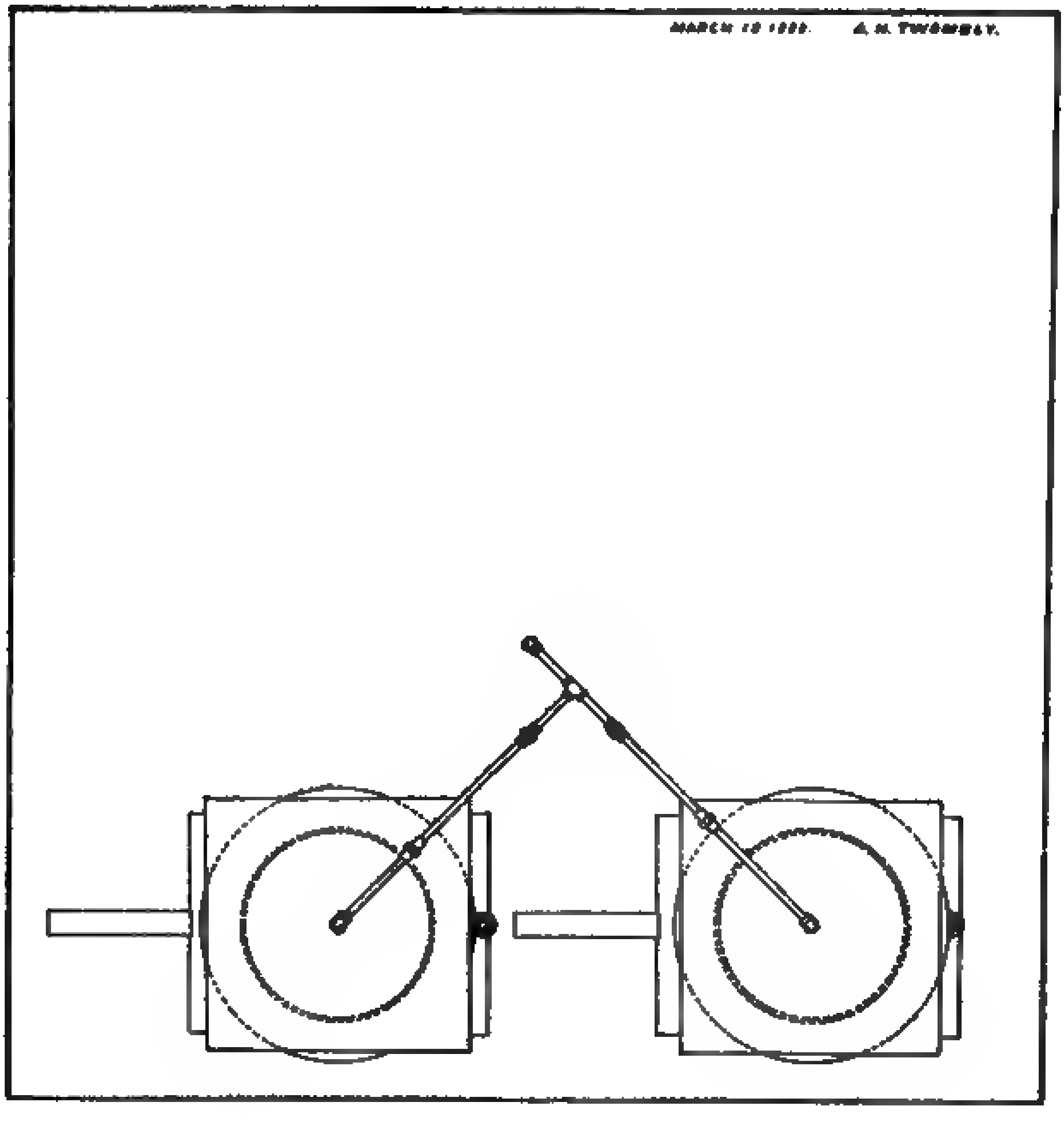
It having been suggested that oil stoves might be used for this purpose, some experiments were made to determine their heating powers, with results which were not encouraging. The odor also would be objectionable if they were not properly trimmed.

AMOUNT OF STEAM USED IN HEATING CARS.

There are all sorts of opinions and statements in regard to the amount of steam taken from the locomotive to do the heating. Some claim that the steam cannot be spared, and that the engine cannot make her time if called on for this extra duty, and others that it makes no perceptible difference in the running of the locomotive. Some even go so far as to say that all the steam required for heating can be furnished through a hole in the boiler no larger than a pin-hole. That neither extreme is correct is shown by the following experiments. It did not seem to be worth while to undertake any very precise work to compare the amount of steam used, when this, that, or the other appliance is used, or this, that, or the other size or amount of pipe, for it does not seem that, in the present stage of development of steam-heating, such information is required.

The winter was so far advanced when the investigation began that there was not sufficient time to perform the work in such manner

PLATE 2.



pressure was needed on the train pipe in the cab, and as it was not possible to get more than five by the use of that orifice, it was demonstrated that an orifice one-eighth inch diameter was too small for the four cars. Next, a one-half inch orifice was substituted for the one-eighth inch, and this worked all right. It was none too large; and it is probable that if the experiment had been made with six cars, with the thermometor below zero, a larger orifice yet would have been needed. As it was, the one-half inch orifice was used in all the tests. These experiments showed the amount of steam used per hour, on each trip, as follows: —

First trip, 4 cars thoroughly heated, . .	334 lbs.	27° outside.
Second trip, 4 cars well heated, ...	306 "	27° "
Third trip, 5 cars insufficiently heated, .	326 "	30° "
Fourth trip, 5 cars poorly heated, . . .	380 "	19° "

The experiments, though not made with an extreme degree of accuracy, nevertheless give the results to be expected in practice with steam-heated cars fitted up like those experimented upon with a sufficient degree of approximation to justify an opinion as to the tax upon the power of the locomotive, and they indicate that the amount of steam required is by no means inappreciable, and, on the other hand, that this amount is not, as a rule, a serious tax upon the locomotive, especially in view of the fact that at the time when steam heating is most needed, *i. e.*, in the coldest weather, the travel on most roads is light.

The result of all these experiments will undoubtedly be a more extended use of continuous heating during the coming winter, and a general improvement in the appliances and in the management of the apparatus. The following conclusions may fairly be drawn from what has been done: —

It is very important that there should be uniformity in couplers. The Westinghouse air-brake one and one-half inch coupling, with a hard rubber gasket, works satisfactorily, railroad employees are familiar with its use, and the patent upon it expires shortly.

In regard to everything else, uniformity is not so imperative.

The main pipe should be as well-protected as possible. If it must be outside the car it should be thoroughly wrapped. A better place for it is between the sills, and in that place, also, it should be

MEETING 378.

The Eco-Magneto Watchman's Clock.

BY MR. CHARLES A. WHITE.

Transmitting Handwriting by Electricity.

BY MR. W. E. GUMP.

The 378th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, October 25th, at 8 P.M., President Walker in the chair.

After the reading of the records of the previous meeting, and the election of new members, the President introduced Mr. Charles A. White, of Boston, who exhibited and described the "Eco-Magneto Watchman's Clock."

Mr. WHITE said: Only a few years ago, an electrical device for recording the movements of watchmen was not known, but the efforts of property owners, insurance companies, and others to make themselves more secure against losses by fire, flood, thieves, etc., or, in fact, to assure themselves of the faithful performance of their duty by watchmen, have led inventors to conceive various devices by which such an end might be gained.

The result has been that today there are many such devices, some mechanical, but mostly electrical, and all, perhaps, more or less liable to criticism, as being too complicated, too delicate in construction, or subject to manipulation by the watchman.

Until now, the electricity in all electric watch clocks has been generated by chemical batteries, which, in themselves, are a constant source of trouble and expense, even to electricians, and a profound mystery to very many people; but the great trouble with these clocks worked by chemical batteries is that they can be so easily manipulated by watchmen, to make false records, and the slightest accident to any part renders the whole system useless.

Now, it is evident that what was needed was a device operated by electricity, that would work strongly and surely, that could not be operated by any method of crossing wires, or by circuits closed anywhere on the wires, that required no delicate springs or the services

England, and was justly considered a brilliant telegraphic marvel. The principle which guided Mr. Cowper in the invention was the familiar law of resultant motion when two opposing forces are combined. It must be observed that the action of a pen or pencil in writing is twofold. There is the "up-and-down" stroke, and the "right-and-left" movement of the pen along the paper, the curved letters being the resultant of these two motions.

The art of writing by telegraph, therefore, consists in suitable apparatus for transferring over wires these two opposing forces, and recomposing them into a resultant motion that shall exactly resemble the original movement.

To accomplish this Mr. Cowper employed two separate telegraphic circuits, each with its own wire, battery, transmitting and receiving apparatus. One of these circuits he made to transmit the up-and-down component of the pen's motion, while the other simultaneously transmitted the right-and-left component. Each continuously varying component was transmitted by causing the resistance of the circuit to vary with the component in question. At the receiving station these two components were recomposed by a pantograph arrangement of taut cords, and the resultant motion was thus communicated to the duplicate pen.

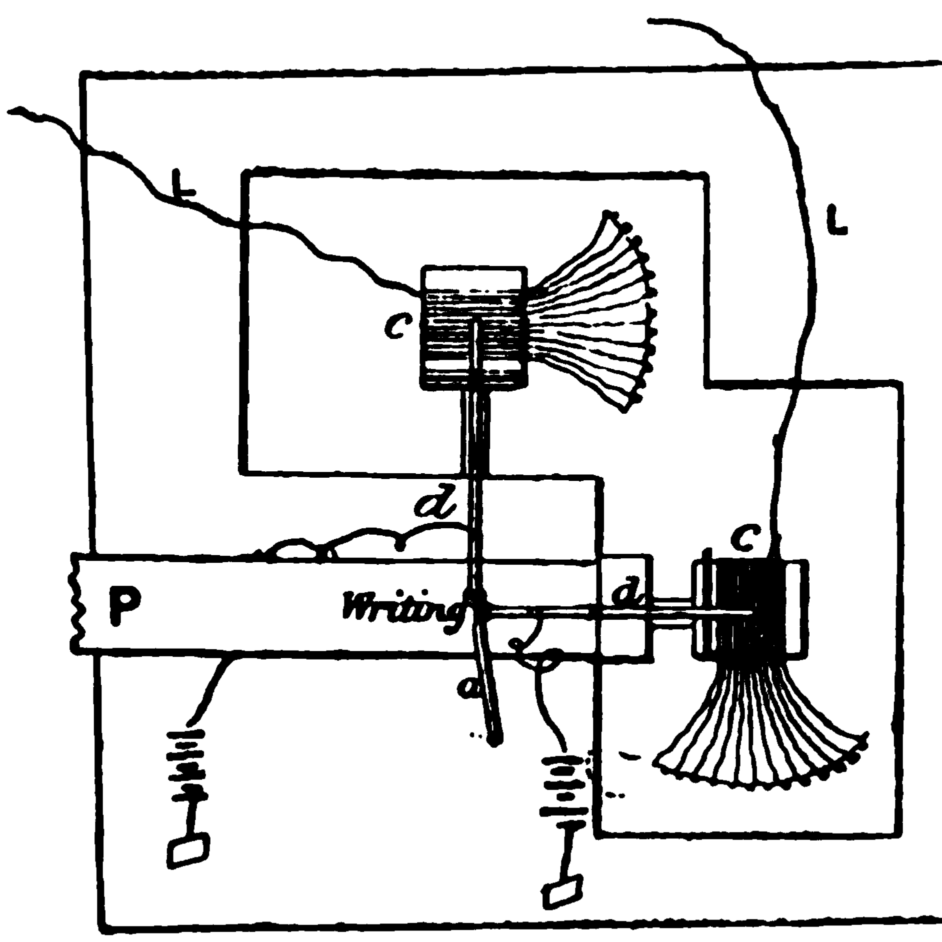


Fig. 1.

The transmitting apparatus is shown in figure 1.

The pen or pencil, *a*, is held in the writer's hand in the ordinary way, and to it are attached two arms, *d d*, one for each circuit. The paper, *p*, is moved underneath the pen by clockwork. The arms, *d d*, are insulated from each other, and each connected to its particular battery, the other pole of said battery being connected to earth. At the free extremity of each arm a sliding contact is fitted,

wire, *i i*, and controlled in their zero position by the electro-magnets, *j j j j*, placed underneath. The line wires pass through the coils, *i i*, to earth. Attached to the point of each needle is a delicate cord. These cords, *n n*, cross each other, and are kept taut by the threads, *o o*, and by the springs, *s s*. The springs exactly balance the strain on the cords from the needles, as long as the resistance in the line is constant, and the needles remain at rest. Where the cords, *n n*, cross, they are connected to a glass siphon pen, which is suspended by a thread, and free to move in any direction.

Now, since the needles deflect in proportion to the strength of the current flowing through its coil, the points of these two needles keep moving with the varying currents sent into the lines by the transmitting pen, and pull the receiving pen in two directions at the same time; and as it cannot follow both motions, it takes a path between them, that is the result of the two forces, and reproduces the original curve made by the transmitting pen.

This was the first telegraph which could really be called autographic. The writing over a circuit of forty miles was very distinct and a fair reproduction. There was a tremor in the writing by the receiving pen, but nothing objectionable.

Mr. J. Hart Robertson was the second inventor in this line of telegraphy, but was, however, unaware of the achievements of Mr. Cowper for some time.

Mr. Gump next described the various steps taken by Messrs. Cowper and Robertson in their efforts to produce a perfect machine, drawings of the different transmitters and receivers being shown upon the screen. The speaker then continued: The transmitter to be exhibited this evening has two series of about thirty carbon disks in each, placed at right angles to each other in a hard-rubber receptacle. Each disk was one-half inch in diameter, and one-fortieth of an inch thick. The normal pressure of each series of disks is adjusted by a screw. The stylus rod has insulated pressure points opposite the piles of disks, and is supported at the base on this spring wire, so that the rod can be manipulated as in writing, and in so doing the pressure points are pressed against springs which press upon the carbon disks, and thus vary the current. It takes the most minute pressure to make a great variation in the resistance, and for this reason the transmitter is placed six inches below where you take hold of the handle to write.

company, and run bare wires among theirs for distances of a mile or more, without the slightest disturbance to the moving pen.

At the close of Mr. Gump's paper numerous questions were asked and answered, after which the meeting was adjourned to enable the persons present to examine the instruments in operation, and also the watchman's clock. Samples of writing transmitted from one part of the room to the other were given to many of those present.

MEETING 379.

The Phonograph and the Phonograph-Graphophone.

BY PROF. H. W. VAUGHAN.

The 379th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, November 8th, at 8 P. M., Prof. C. R. Cross in the chair.

The records of the previous meeting were read and approved.

The chairman then announced the subject of the evening to be a description and exhibition of the Phonograph and the Phonograph-Graphophone,— inventions of Edison, Bell, and Tainter. He then explained the acoustic principles involved in the operation of the machines, illustrating his remarks by experiments with tuning forks, organ pipes, etc.

After this explanation the chairman introduced Prof. H. W. VAUGHAN, of New York, who briefly described the principal features of the machines, and indicated some of the uses to which they could be put.

At the close of Prof. Vaughan's remarks a vote of thanks was passed to the speaker for the exhibition. The meeting was then adjourned to give the persons present an opportunity to personally inspect and listen to the machines in operation.

determining some hundred or more dips and strikes over a considerable area, to get a reliable average, and assuming that the dip and strike of the copper vein was the same as that of the rock, we made a diagram which gave us the rise or fall of the copper vein at all points of the compass. We then, while running the line, and in selecting each new direction, had only to point the compass in such a direction that the rise or fall of the ground would be the same as the rise or fall of the vein for that bearing. Then, provided our premises were correct, we could follow this line with confidence that we were on the outcrop of the copper vein, even though no surface indication whatever could be found. In this way a line about half a mile long was run through thick forest along the supposed outcrop of the vein. We found little in the way of surface indications on this line until we came to the end of it, where we found a group of costeaning ditches and prospecting pits, which indicated that they belonged to the same copper vein as the mine. Prof. Richards gave some interesting accounts of their camp life. He also expressed himself as being perfectly satisfied that the experience gained by the students was of great benefit to them.

At the close of Prof. Richards's remarks the chairman introduced Prof. F. W. Clark, who gave an account of the under-ground work of the school.

Prof. CLARK said: The under-ground work was divided as follows,—each squad worked four days on mine survey, four days on drilling and blasting, two days on timbering, and a day each on track and cars, engine and ropes, and rock drills. After the work common to all was finished, those who chose to do more work of this character located two or three points in the mine on the surface, and several vertical shafts for the future working of the deposit, did additional timbering and other mine work, examined and reported on neighboring mines and works, made a section on the line of two of the slope shafts, etc.

As will be seen by the plan and section of the mine maps, the workings are very irregular and slope at an angle of 35°, but vary from 15° to 70° in different parts of the mines. The deposit varies in thickness from four feet to nearly sixty feet. The roof or hanging wall is supported by timbering and heavy pillars of ore, so that the mine is a very open one. Great trouble was experienced in holding

Department. It was also decided to allow all third-year students at the Institute, who were properly qualified, to attend this school without the payment of extra tuition; and applicants, not students of the Institute, were to be admitted after passing a satisfactory examination, on the payment of a fee of twenty-five dollars.

There is a growing demand in this country for good topographers; and it is a fact that our general and State governments, in prosecuting topographical surveys, have found it difficult to obtain from engineering schools skilled assistants in this branch of work, the greater demand for constructing and railroad engineers having forced the subject of topographical surveying into the background. It was in some degree to meet this demand that the present school was planned.

Columbia College, New York city, has for some time past maintained a summer school of geodesy, and summer courses, in general field work, have from time to time formed part of the course of engineering instruction in other scientific schools; but there are some individual features about our own course that may warrant special mention.

Reference is here made to the fact that especial attention has been given to methods of repesenting the actual relief and contour of the ground, and to the elucidation of the intimate connection between topographical phenomena and the underlying geological structure.

To best convey an idea of the aim and purpose of this school, a short account will be given of the work done during the month of June, 1888, at South Deerfield, Mass.

South Deerfield, on the Connecticut River, had been chosen as the field of operations for several distinct reasons.

First, there were the interesting topographical and geological phenomena presented by Sugar-Loaf Mountain, and the fine terraces of the Deerfield and Connecticut Rivers.

Second, there were the superior facilities offered for base-line measurement and the connecting triangulation.

Third, there were the many railroad lines, offering every facility for excursions to adjoining territory.

Fourth, there was the excellent opportunity offered for conducting the hydraulic measurements, offered by the long straight reach of the Connecticut River at this point.

from this standard, it was necessary first to determine the number of pounds of pull necessary to stretch the tape enough to make up for the shortening due to sag. Secondly, to determine the changes of length due to changes of temperature, and, thirdly, to make allowance for these changes in connection with amount of pull.

The determination of the modulus of elasticity of the tape, and the shortening due to sag and the co-efficient of expansion, were all matters of field work and computation on the spot. The steady pull necessary for accurate work was attained by attaching the end of the tape to a hand-screw held against a heavy stake driven firmly into the ground. The amount of pull was measured by a spring-balance, the variations of which, from a standard, were subsequently determined in the physical laboratory.

The profile across the valley was a combination of spirit-leveling, stadia work, and trigonometric leveling from base lines, and brought out many interesting and novel problems arising principally from the natural difficulties of working on the nearly vertical slopes of Sugar-Loaf Mountain.

Trigonometric leveling from the long base line to the summit of Sugar-Loaf and from two shorter base lines agreed within a fractional part of a foot.

This elevation, determined by these different independent measurements, furnished a standard of comparison for the results obtained by the hypsometric instruments referred to previously.

The astronomical work was very slight, owing in great part to the lack of preparation of the students for this kind of work.

The topographical work, proper, was carried on exclusively by plane table methods. For this work a region was first selected possessing a somewhat complicated and irregular contour, and each student was furnished with a small rude sort of plane table and a compass sight alidade. A base line of some 700 or 800 feet was quickly measured and plotted on each one of the plane table sheets. Each student then carried on an independent graphical triangulation over the area selected for study, using, as far as possible, natural objects for signals. When this triangulation work had been finished and tested, the next step was the sketching in of the configuration of the surface of the ground by a system of line shading, these lines being drawn always in the direction of contour lines, and indicating, by their spac-

At the close of Prof. Burton's remarks the chairman gave an account of the work in hydraulics done in connection with this course.

Prof. SWAIN said: The hydraulic work was executed during the last week, and consisted in measuring the flow of the Connecticut River by various methods. Two parallel lines, 350 feet long, were measured off, one on each bank of the river, and stakes driven every 50 feet. Two gauges were established for reference. The stream was then cross-sectioned, at each station soundings being taken every 50 feet across the river (which was about 1000 feet wide), giving therefore eight cross sections at equal intervals of 50 feet apart. The average depth of the stream, for the entire distance of 350 feet, was then computed at short intervals across, and the average cross section plotted, and this average cross section was used in the computation of the discharge from the float measurements.

These float measurements were made by the use of double floats of tin, of the kind used by Gen. Ellis in his measurements on the same river. It was designed to obtain with these floats the velocity of the stream at equidistant intervals of 50 feet across the river, three floats being sent out from each point, one of which was placed with the lower float about at mid depth (of the average depth), while another was arranged with the lower float close to the surface, and a third with the lower float close to the bottom, or as close as it could be without touching during its passage from transit line to transit line. Transits were set up on the west bank, 350 feet apart, that is, at the upper and lower transit lines. Floats were sent out from points above the upper line. The time which they took in passing through the distance of 350 feet was measured by the stop watch, and the distance out from the bank, at the upper and lower transits, was determined by sighting on them from the instruments at the instant when they crossed the lines. The observations taken by this method were plotted, and the quantity discharged by the stream determined by various methods.

Measurements were also made with the current meter, two kinds of instruments being used, namely, the form used by Fteley and Stearns, in which the meter has to be raised to the surface in order to count the number of revolutions; and the electrical meter, used by Gen. Ellis, in which the number of revolutions is recorded by electricity by a counter

forming curls twisted in opposite directions, and united, not by a bead, as in the beaded lightning, but by a white edge where the process of reversing its motion goes on, as seen near the center, while near the end it presents the appearance of a curl pulled sidewise, being thin and narrow,— afterwards proceeding in a more regular manner than before. No possible shaking of the camera could produce this curled appearance.

That currents of electricity are influenced by the medium through or upon which they travel is seen in figures 3 and 4, and to the well-known theory that the resistance of the air changes its direction may be added that the current changes in size and contracts in volume as it enters the earth, as seen in figure 3.

If we compare the size of these currents with the trees or other known objects, seen in the same photograph, taking into consideration the distance each one is from the lens, one must, by comparison, judge the size of large currents to be, while passing through the air, *several feet* in diameter. Distance must always be considered in judging the size, for as the current goes from the lens its image on the negative gets smaller, and larger as it approaches it.

Sparks from an induction coil or Holtz and other machines give the same indications of the three motions found in the lightning. They are easily photographed. The variety is not so great as in lightning, but one has an opportunity here of varying the current in many ways.

The three motions, the reversing of the rotary motion in the continuous track of a spark, as well as the bead, are found in these currents as in lightning, and adds proof that these and lightning currents are similar.

A large number of photographs of lightning and artificial currents were thrown upon the screen, and minutely described by the lecturer. He called attention to some flashes which approached and receded from each other, like the contour lines of a vase. This, he thought, could be explained by a theory of attraction and repulsion; and in referring to one case, where several flashes occurred on the same plate, he thought that it was not only possible to point out, by this theory, the flashes that came simultaneously, but also to show, by the theory of rotation, what he supposed to be the return current, as he finds the

Having removed the door, including the microphone contact and the mouth-piece, from the transmitter, it was fastened to the table, leaving space between it and the table for an organ pipe (512 complete vibrations per second), which was used as the source of sound.

To obtain a sound of constant intensity the pipe was blown by means of an air blast driven by the engine in the Rogers Building. The air was regulated by two pressure regulators, one allowing part of the air to escape, the other balancing the air pressure by a column of mercury. The hight of the mercury could be changed at will.

The pressure in the Blake contact is regulated by the attachment of the carbon electrode to a spring, whose tension is adjusted by a screw. In addition to the spring, which was used for preliminary adjustment, pressure was applied by means of a lever arm carrying a scale-pan at its center, one end of which rested on the electrode; the other, carrying a knife-edge resting on glass, acted as a fulcrum. The scale-pan was covered by a piece of velvet, in order that the addition of weights might cause no jar at the contact. In the experiments it was found that any attempt to take off weights had the effect of disturbing the adjustment of the contact to such an extent as to break the series. This same result was frequently brought about by the jarring of the ground from the street traffic.

A more powerful induction coil was used than that in the Blake transmitter. The resistance of its primary was 0.5 ohm, and of its secondary, 899 ohms.

Various forms of battery were experimented on, with varying arrangements of the cells, to observe the effect of changes in electromotive force and in resistance. The currents to be measured were very small, and consequently some extremely sensitive form of electro-dynamometer was required. One of the Kohlrausch pattern, with movable coils, was used, which was wound with No. 40 (B. and S. gauge) double silk-covered wire. The two outer coils might be used either in parallel or in series with each other, and in either way with the inner (suspended) coil.

This dynamometer, which differed in some of its details from the instrument as ordinarily made by Hartmann, was constructed especially for experiments of this nature by Mr. Otto Scholl, the mechanician of the Laboratory.

Having completed the necessary apparatus, they proceeded to

intensity but improves in quality. In all our experiments the same form of curve represented the variation of pressure and current, and in all the best sound was transmitted directly after the maximum current.

In experimenting with electro-motive forces greater than 3 volts we met with unsatisfactory results. Good sound was not transmitted except under heavy pressure, and all attempts to obtain satisfactory measurements failed on account of the well-known disturbances set up in the microphone by the current itself.

In certain of their experiments the resistance of the primary circuit was diminished by joining a number of cells in parallel. The uniform result was that the sound transmitted was louder.

The results of the experiments may be summed up as follows: —

The resistance of the primary circuit, and especially that of the battery, should be as low as possible; the pressure at the contact should be no greater than is required to transmit good sound,—that is, it should be a little greater than that required to give the maximum current; with the present form of Blake contact, no electromotive force greater than 2 volts should be used; and, finally, the contact should be carefully guarded against jarring.

The following spring Miss Annie W. Sabine undertook a study of the variation of the current in the secondary circuit of a microphone transmitter, as related to variations in the normal pressure and in the mass of the electrodes of the microphone. This forms a continuation of the work just described.

The instruments used were similar to those previously employed by Messrs. Patterson and Tucker.

The microphone contact was set into vibration by the sound of a stopped organ-pipe (C_4 of 512 vibrations), kept as constant as possible by means of an air-blast furnished with a regulating air-chamber. Weights were gradually added to the upper (anvil) electrode, so that the mass of this and its pressure on the lower electrode were thereby increased by measured amounts. The weights added were usually in the form of thin copper washers, weighing $\frac{8}{10}$ of a gram each, though fractions of this weight were used in some cases. One chromic acid cell was used as a battery.

The character of the results obtained will be found in Table II, which, when plotted with the abscissas representing the normal press-

alone to be varied, but the effect of the addition of weights, as in the method of experiment adopted, is to increase the mass at the same time that the normal pressure is increased, and under these circumstances the effect of a sound-wave of given intensity will necessarily be to give to the corresponding pressure-variation a variable value, increasing with the added mass, and hence, with the form of apparatus used, as the normal pressure is greater. The effect of this will be to cause at first a gradual increase of current in the secondary, which increase is succeeded by a diminution of current when the mass is still further increased.

The momentary changes in pressure, Δp, $\Delta p'$, $\Delta p''$, etc., due to the sound-waves, and corresponding to loads and normal pressures p, p', p'', etc., have increasing values within certain working limits, owing to the increasing mass of the anvil electrode. The currents in the primary also increase, though at a gradually diminishing rate, as the pressure between the electrodes is increased, so that the increments of current, Δc, $\Delta c'$, $\Delta c''$, corresponding to the pressure-changes Δp, $\Delta p'$, $\Delta p''$, have increasing values up to some point, as a, after which they decrease. This being the case, it is evident that the current in the secondary will at first increase to a maximum, and afterwards diminish, since the currents in the secondary corresponding to pressures p, p', p'', etc., will be proportioned to Δc, $\Delta c'$, $\Delta c''$, etc., and this is precisely the curve which is obtained in the experiments. The explanation just offered seems therefore to be the true one.

The matter was still further tested by carrying out a set of experiments similar to those already described, except that the variations in normal pressure were brought about by means of a spring instead of by adding weights. In such a case the successive values of Δp, would be of the same magnitude, while Δc would continually diminish. The current in the secondary should therefore have its maximum value when the initial normal pressure is least, and continually diminish as that pressure becomes greater.

The experimental results verified this conclusion. The curve is approximately a straight line. It is possible that the deviations from this are due to instrumental imperfections, as the apparatus used did not allow of more than an approximate determination of the pressure applied by the spring.

The variations in the secondary current which occur under dif-

milliampères. The length of the line from 95 Milk Street to the Institute was about two miles; that of the line to New York was two hundred and sixty miles.

Table III.

Transmitter.	Sound.	Locality of Transmitter.	Current.
Blake.	Talking.	95 Milk Street.	.185
"	Singing.	"	.52
Hunnings.	Talking.	"	.28
"	Singing.	"	.78
"	Talking.	New York.	.02
"	Counting.	"	.02—
"	Organ Pipe.	"	.01+
"	Counting.	Rogers Labroatory.	2.05
"	Talking.	"	2.20
"	Organ Pipe.	"	1.24

The speakers were Dr. W. W. Jacques, of Boston, and Mr. F. A. Pickernell, of New York, who kindly aided us in our work. They are both experts in the use of the telephone, and accustomed to work with each other. The pitch, as well as the loudness of the sounds used, was kept as nearly as possible the same. The vocal sounds transmitted were spoken in a very loud tone, and close to the transmitter.

The figures obtained with the long line to New York are very instructive, as they give some knowledge of the loss of current which is sustained in long distance telephony. When the transmitter was at the Institute, near to the dynamometer, the full current produced by the former passed through the latter instrument, while, when the transmitter in New York was the one used, it is clear that only what was left after all leakage, etc., passed through the measuring instrument. Assuming the sounds as produced at the two stations to be of approximately the same pitch and loudness, it appears that only about one one-hundredth of the original current produced at the transmitting station is finally utilized at the receiving station. It further appears from these figures that about 13 per cent of the current produced at the transmitting station was utilized in ordinary telephonic transmission over the local lines from 95 Milk Street to the Laboratory.

season. This cannot be expected to continue forever, and I do not think it too presumptuous to say that in all probability that development will be reached in the course of about twenty years, so that by 1910 the South will have attained the highest point in its cotton production. This means a crop of about thirteen and a half million bales. For the production of this quantity of cotton it would require 35,100,000 acres of land, yielding, on the average, 175 pounds of lint to the acre. This acreage is a little less than 8 per cent of the total area of the cotton States, and nearly 70 per cent of the tilled land enumerated in the census of 1880. With this acreage the larger part of the best land in the South, at present in suitable condition for cotton cultivation, would be in demand for the growth of cotton. Whatever the future production of the United States may be, it seems safe to say that the time is not far distant when other cotton-growing countries will be called upon to contribute a much larger proportion of the world's supply than is now the case. Whence, then, is this additional supply to come? It is evident it must come from some portion of the zone within 30° south and 35° to 42° north of the equator. Naturally, India would be the first looked to for supplying the larger portion of the deficiency, but experiments and years of cultivation have demonstrated that other countries also have favorable conditions in climate and soil for a satisfactory yield of the staple.

We do not presume that central Asia will ever become a great cotton-producing region in ministering to the wants of the cotton-manufacturing industries of the world or in supplying any large portion of the anticipated deficiency, but we believe that it has a future in this direction that is worth our while to consider, if in no other connection than with the manufacturing wants of Russia. The particular prominence of Central Asia, at this time, is because of the special efforts on the part of the Russian government to convert it into a highly-productive cotton-growing region, whence can be obtained the chief supply for the cotton factories of the empire. The annual imports of cotton into Russia amount to about 300,000,000 pounds, or 750,000 bales. A large portion of this quantity is American cotton, though, in 1887, only 155,753 bales were received direct from the United States. The object of Russia is to avoid these importations by raising the necessary amount for its manufactures

certain it is, great improvements will have to be inaugurated before it attains any position of this kind. Bokhara cotton today is trashy stuff, as it appears upon the market, and it possesses few qualities in length and uniformity of staple or cleanliness to recommend it for manufacturers' use. This is partly inherent, and is also due to indifferent harvesting and to the crude inplements employed in freeing the lint from the seed. Some progress has been made of late in the introduction of better methods of ginning, in the use of saw gins; but this can be better said of the methods partly in operation about Tashkend. As it is now, a large portion is scarcely worth the cost of transportation to Moscow; yet it is here that many of Russia's hopes are centred for that production which is to render Russian manufacturers independent of an American supply. Soil and climate may be propitious, but the laborer has much to learn, which means more than its simple declaration. Experiments that have been made with the sowing of American and Egyptian seeds have not proved as satisfactory as anticipated. The first year's production usually compares favorably with the original, but a deterioration at once takes place, which is readily perceptible the second year and thereafter. The same experience has been had with the yield of cotton from American seeds in other countries where experiments have been conducted. The best cotton, in my opinion, for any country, is that raised from native selected seeds under improved methods of cultivation. Hence, it is my belief that the best cotton seeds for Asiatic Russia are carefully selected seeds that are indigenous to the soil. And this has proved to be true in a certain degree in our southern States. My own observations have demonstrated to me the impracticability of reproducing sea-island cotton in possession of its superior characteristics, as represented by its Edisto type, on Galveston Bay, or anywhere on the coast of Texas, though apparently under like conditions regarding soil and climate. I may be mistaken in my judgment concerning the proper seeds to cultivate from, and it almost seems as if such were the case in the face of the many reports of the great improvements occasioned by the planting of American seeds, as has been noted by consular officials regarding the cotton from such seeds raised in the Erivan province, Caucasia, and elsewhere. Yet I am inclined to think that retrogression will in time follow, unless equally favorable climatic and other conditions can be found, which have not yet been

Khivan oasis is on the left banks of the Amu Daria, and is more or less fertile, but, being only 200 miles long and 30 miles wide, it is not likely to become a cotton region of the same importance as that lying on the slopes and in the valleys of the western spurs of the Tian Shan Mountains.

Comprehensively speaking, Turkmenia has no cotton future. It may be considered as a vast desert, with only an occasional well of fresh water for a district, perhaps of 130 square miles. In the southern portion four oases exist, through which the trans-Caspian railroad passes. The most important of these oases is that of Merv, which, after all, is not a natural one, but made so by irrigation many years ago. Experiments have lately been conducted in the vicinity of Merv in the cultivation of cotton from American seeds. Fifty pounds of seed are sowed to the acre, and during the growth of the plant the land is irrigated three different times. The full crop yields an average of 1165 pounds of seed cotton, or 217 pounds of lint to the acre. This would indicate a yield of only 18.6 pounds of lint to 100 pounds of seed cotton, though it is stated American saw gins are used. The inference might be that the operation of the machine is very imperfect, or that there is a degeneracy in the character of the cotton plexus, either in density or length of staple, which I am inclined to believe is the case. I have been further informed that the cost of cultivation is about $17.50 per acre, but it is expected that this will be soon reduced at least one half, and that the yield of lint cotton per acre will be increased to 300 pounds.

Many efforts have already been made to ameliorate the varieties of cotton planted, and experiments have been made with American seeds. The variety chosen for this purpose was Sea Island, but it never seemed to occur to the reformers that Sea Island cotton owed its merit entirely to the fact that it was grown on islands on the sea coast, and that when sown on uplands or in the interior it lost its good qualities. The cotton planted in Tashkend and near Samarkand came up and grew beautifully; in fact, it kept on growing until it reached a hight of eight or nine feet, till winter came on, before any of the bolls had a chance to ripen.

A Russian writer, familiar with the agriculture of Central Asia, says that the production of cotton in the territories about Khiva, Bokhara, Khokand, and Tashkend has in the last seventy-five years

mean temperature for the year was 58.1 degrees in a range from 3 degrees to 104 degrees. At Tashkend the mean temperature was 55.7 in a range from 10 degrees below zero and 101 degrees above. The rainfall for the year, in the two places, was about 15 inches, and the mean relative humidity was about 64 degrees. I have been unable to obtain the meteorology of any portion of Central Asia for the cotton-growing season, therefore no comparison, other than yearly, can be made with the meteorology of the southern States. In 1880 the mean annual temperature at Augusta, Ga., was 65 degrees, ranging from 7 to 102 degrees. At Vicksburg, Miss., the mean annual temperature, for 1880, was 66 degrees, ranging from 12 to 101 degrees. The annual amount of precipitation for the two places was respectively 48 and 84 inches. That for Vicksburg was unusually heavy, the average annual precipitation being nearer 60 inches. The mean relative humidity for the two places was about 69 degrees. The great difference in the yearly amount of precipitation in Central Asia and in the American southern States will be particularly noted, and the importance of a perfect system of irrigation, with reservoirs and canals, under excellent regulations, will be appreciated for the former country. There is much to be desired to make the comparison good for purposes concerning the cultivation of cotton. Average meteorologic conditions are much more unsatisfactory for Central Asia than for our southern States. The conditions are far more uniform for the latter than the former. The surface elevation of the cotton-growing region of the southern States is within a few hundred feet above the sea level, while that of Central Asia varies from a few hundred to many thousand feet, making the climate, as about Khokand, partake of complex characteristics peculiar either to the tropic or temperate zone. Instead of one vast area being suitable to cotton cultivation in Central Asia, only isolated spots, comprising more or less territory, are to be found. In the valleys and along the lower slopes of the mountains the winters are usually mild, with little snow, while the summers are long and hot, with little rain.

The building of the trans-Caspian railway from the sea to the valley of the Zarafshan is an enterprise of the greatest importance to the material welfare of Russian Central Asia. Its construction was begun in 1880, with no other interest than to transport troops, food, and forage some fifteen miles into the interior. In 1885 mili-

of territorial aggrandizement. The extension of her boundaries in Asia, though apparently aggressive and possessing military significance, has thus far been confined to ethical and political lines, and would remain so even if Bokhara and Kashgar were included. Russia's political power is fully established in Central Asia, and there is no danger of her losing her present territorial possessions; and being fully aware of this she has inaugurated a policy having in view the industrial progress of the country.

MEETING 384.

Statistical Tabulation by Machinery.

BY MR. CHARLES F. PIDGIN.

The 384th meeting of the SOCIETY OF ARTS was held at the Institute, on Thursday, February 14th, at 8 P. M., Prof. Davis R. Dewey in the Chair.

After the reading of the records of the previous meeting, the chairman introduced Mr. Charles F. Pidgin, of Boston, who read a paper on "Statistical Tabulation by Machinery."

Mr. PIDGIN's opening remarks related to the origin of statistics. The science, as regards census-taking, is of great antiquity, for there are several allusions made in the Bible to the numbering of the people, and the book of "Numbers" is the census-volume of the Bible.

The manner of counting first used was undoubtedly to stand the people in rows or assemble them in groups, and then actually count or number the individuals. Natural steps forward would be made after the introduction of letters and figures, and signs, symbols, or marks of various kinds would be used to record the enumeration and the necessary aggregations in order to arrive at totals.

The two principal operations in tabulating are counting or tallying one at a time, and addition, or the aggregations of large numbers. Besides these two mathematical processes many averages and percentages have to be figured for use principally in analyses of statistical tables.

Counting or tallying was originally done by the use of peas, beans, shells, which were dropped into some recepticle, and then counted to arrive at results. The next move would be to make dots or checks to represent persons or things, and then count these dots or checks. We are all familiar with the four perpendicular and one cross line to indicate five. In 1875 I prepared and copyrighted a "Self-Counting Tally Sheet." Upon these sheets the dots were already printed, and the tabulator, by encircling the dots and adding certain checks, could tabulate 9000 points on a sheet six by nine inches; and, what was of particular importance, could carry out the results at once, the sheets being so arranged as to "self-count" the check marks. The self-counting tally sheet was used to prepare the population and social statistics of the State Census of 1875. Seaton's tallying machine, used in the United States Census of 1880, was ingeniously arranged to receive the check marks in prepared columns, but it was not self-counting, and the aggregations were necessarily laborious and tedious. A tallying machine used in the Royal Bureau of Statistics at Rome has figures on the peripheries of wheels, and when these upturned figures are inked with a printer's roller, impressions may be taken on paper for use as bulletins. In 1882 I used, for the first time, a mechanical device for tallying or counting. This was named the "Pascal" counting machine. It registers from 1 to 999, and beyond that, by an ingenious device, its capacity may be indefinitely extended. The single machine is intended to count one at a time only. By combination of a number of machines the series may be used for addition or multiplication.

The Pascal machine is the foundation of the "Automatic Door Counting Machine," by means of which the population and social statistics of the Massachusetts State Census of 1885 were prepared. By this machine a great gain is made over previous methods, both in speed and accuracy. With the old form of tabulation sheet but three points of statistical information were secured at a time, while the machine referred to has a capacity of 144 points at one handling of

The speaker next referred to his "Electrical Adding Machine." This machine is based upon the decimal disintegration of numbers, — the same principle as was made use of in constructing the "Self-Counting Form for Adding Values, Quantities, and Numbers." The capacity of the machine likely to be most used is 999,999,999, but the capacity may be easily extended indefinitely. Machines can be easily constructed on this plan to add yards, feet, and inches; pounds, shillings, pence, and farthings; fractions,— in fact any collocation of units, the machine doing the necessary reductions automatically, and showing a consecutive total on a dial plate.

Electricity has been adopted as the motor, because it is the only power that will operate the automatic carrying device, thus saving the eye, ear, or finger the necessity of "carrying." It reduces addition to simple notation, or the writing of numbers the same as they would be written on a sheet of paper. When the "writing" on the machine is done, the numbers are added, and the total is visible upon the dial plate of the machine. Any digit may be put upon the machine with one motion, that is, a "9" can be added as easily as a "1." The advantages of the machine are numerous. It avoids brain wear. Ten hours' work with the machine is less fatiguing than three hours with pencil and paper. It places the ordinary clerk on a level with the expert accountant, and yet aids the expert by lightening his labors. Its comparative efficiency depends naturally upon the operator. Other things being equal, its efficiency is from two to six times that of the old method of computation. Besides, the weary brain is prone to error, but there is no reason why the electrical adding machine should do any the less accurate work at six o'clock in the afternoon than at nine o'clock in the morning. A cog-wheel adding machine may be broken, and the machine keep on working, but naturally giving erroneous results. On the other hand, as soon as anything interferes with the accurate working of the electrical adding machine — *the machine stops!* This machine, by a simple process, may be used for multiplication, but it is not intended to do subtraction or division.

With a view of inventing a machine, or rather a system, which would give the same opportunities for addition as the Automatic Door Counting Machine does for tallying, I devised the "Chip System." The chips are contained in a case, and are taken from it the same as

them to do more and better work for the salaries paid them. They will make it possible for statistical officers to prepare voluminous reports with small appropriations, and will enable state and national governments to tabulate and aggregate census and industrial returns in less time and for less money than by old methods.

The speaker closed with a humorous account of a supposed visit, in a dream, to the mythical city of Statistica, where statistical records are carried to a laughable extreme. Several of the machines described were exhibited in operation.

MEETING 385.

The Nature and Uses of Asphalt.

BY CAPT. F. V. GREENE.

The 385th meeting of the SOCIETY OF ARTS was held at the Institute, on Thursday, February 28th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, the President introduced Capt. F. V. Greene, of New York, who read a paper on "The Nature and Uses of Asphalt."

Capt. GREENE said: Asphalt is a variety of bitumen, found in a native condition and not manufactured, and in a solid form is commercially known as glance pitch. Glance pitch is found in limited quantities in various parts of the Rocky Mountains and in Texas. It is very pure, and is used to make a high grade of varnish, but its brittleness makes it useless for paving or roofing compounds.

The asphalt of Trinidad is found in a so-called "lake," about 130 feet above the sea level, on the island of that name. The "lake" is a level tract, about 114 acres in area, of brownish material of an earthy appearance. It is sufficiently hard to bear the weight of carts and animals, and yet its consistency is such that excavations fifteen

joints of the bricks, the bricks being heated and dipped in hot asphalt, and the joints poured with similar material after the bricks are laid.

As a roofing material asphalt is used in the form of asphalt cement, very similar to paving cement. The roof is covered with one or more layers of felt; on this a layer of the cement is poured, and before it has cooled fine gravel or pebbles are spread over it.

The amount of asphalt used for paving is about ninety-five per cent of the total consumption.

I shall endeavor to show that the asphalt pavement is the latest, and, all things considered, the most satisfactory solution of the paving problem yet devised. It is not as durable as cast steel, nor as noiseless as velvet, nor does it afford as firm a foothold as the loose earth of a race track; but it is much smoother and less noisy than stone, much more durable than wood or macadam, is waterproof, contains no decaying vegetable matter, can be kept perfectly clean at comparatively small expense, is less slippery under ordinary conditions (as shown by careful observations in Europe and America) than either wood or stone, and it enables larger loads to be drawn by the same force and with less wear on vehicles than any other form of pavement ever used. It has thus many advantages and fewer defects than other pavements in common use.

The speaker next gave a brief history of pavements in general, so as to trace the origin and development of asphalt pavements.

He said that no improvement has ever been devised upon MacAdam's system as a road-covering outside of cities. It has also been widely introduced within cities. London has about 600 miles, and Paris 100 miles of it today. In America it has always been popular in New England cities,— three fourths of the streets of Boston are paved with it,— but it has not found favor in other cities except on streets reserved for pleasure-driving only.

Its advantages are a firm foothold for horses and a reasonably smooth surface. Its defects are heavy resistance to traffic, great cost of maintenance, and the impossibility of keeping it clean. When sprinkled it is always muddy, and when dry it is invariably dusty. These defects are inherent, and cannot be remedied. The Paris Budget shows that it costs over $900,000 per annum in that city for the single item of repairs to macadam pavements. This is equivalent to 45 cents per yard per year. It is estimated that the annual cost

In London the first cost has been about $3.75 per yard, and the maintenance 18 cents per yard per year, the street to be delivered at the end of seventeen years as good as new. Including first cost, the total expense is 40 cents per yard per year.

The success of this pavement in Europe gave rise to a demand for such pavements in America, but the expense of transportation of the rock from France was so great that inventors sought to find a substitute. They first tried the tar produced in large quantities at the gas works, which they erroneously supposed to possess the same qualities as the natural bitumen in the asphalt rock. This was combined with sand, limestone, sulphur, sawdust, etc. The material did not look unlike the real asphalt, and a craze for such pavements started in Washington in 1871, and spread all over the country.

The majority of these efforts were complete and costly failures, and, as they all claimed to be asphalt, the result was to create a prejudice against all pavements of that character, which it required years of careful experiment and proof to overcome. The defect of them all lay in the tar, which contained volatile matters which evaporated under the influence of the sun, and left the pavement a mass of dry black powder.

A Belgian chemist conceived the idea of using the asphalt of Trinidad as the cementing material, knowing that it had been exposed for centuries to a tropical sun, and that the sun's rays could have no further effect on it. With this he combined clean sharp sand and a small amount of powdered limestone. The sand in it afforded a firmer foothold for horses. It was used on a part of Pennsylvania Avenue, in Washington, in 1876; the asphalt-rock pavement of Paris was used on the other part, and they have been in constant use ever since. The French pavement proved more slippery and more costly than the Trinidad, and no more of it was laid; but the Trinidad asphalt gave entire satisfaction, and has been constantly laid with succeeding years, until now its area in Washington alone is but little short of one million yards. After seven years' successful use in Washington other cities began to use it, Buffalo being the first, and it now rivals Washington in extent of its use. It is now used in thirty-four cities, the total area being about four million yards.

These pavements are laid on a solid foundation of concrete six inches in thickness. The asphalt surface is two and one-half inches

times as heavy as on the ordinary stone pavement. The former can be kept perfectly clean at small expense; the latter has one-fifth of its surface composed of joints filled with stable filth, which cannot be removed in cleaning.

If some one gives voice to the current belief that horses are constantly falling on the asphalt, I will show him the result of careful observations in ten different cities on 786,000 horses, of which eighty-four fell on stone pavements, and only seventy-one on asphalt. The proprietors of the livery stables of Washington and Buffalo say that they invariably use the asphalt in preference to the stone pavement, and that there is far less injury to horses, as well as to their vehicles, on the asphalt.

At the close of the paper the President extended the thanks of the Society to Capt. Greene for his very instructive paper, and declared the meeting adjourned.

MEETING 386.

Artificial Fertilizers.

BY MR. WALTER S. ALLEN.

The 386th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, March 14th, at 8 P. M., Prof. L. M. Norton in the chair.

After the reading of the records of the previous meeting the chairman introduced Mr. W. S. Allen, of Boston, who read a paper on "Artificial Fertilizers."

Mr. ALLEN said: The artificial fertilizer industry, now one of the most important of the chemical industries, is purely modern in its development, the foundation having been laid in 1840 by Liebig.

Liebig's theory, which stands today as the basis of all agricultural chemistry, may be expressed in a few sentences, as follows: —

The most important of the more crystalline phosphorites are those of the province of Estramadura, in Spain; those of the Duchy of Nassau, in Germany, known as the Lalui phosphorites; those of southwestern France, known as Bordeaux phosphates; those of northwestern France and Belgium, and the South Carolina phosphates of our own country. Among the other raw materials furnishing phosphoric acid the most important is the slag from the Thomas Gilchrist basic still process. This slag, which is rich in phosphate of calcium, is usually simply ground, and used in that condition as a fertilizer.

Many fertilizers contain potash, and at the present day the only source of this is the Slassfurth salts, which is found in central Germany.

When fertilizers contain nitrogen the sources of it are numerous. As nitrogenous materials found in commercial fertilizers the following may be named: nitrate of soda, sulphate of ammonia, dried blood, fish scraps, cotton-seed meal, linseed cake, castor-oil pomace, dried and pulverized scraps from slaughter houses, hoof and horn shavings, hair, leather scraps, shoddy waste, etc.

Great difference of opinion exists as to the relative advantages of these different forms of nitrogen, but as a rule the manufacturer uses that form which to him is cheapest.

As regards the relative value of sulphate of ammonia and nitrate of soda, field experiments indicate that each exerts a favorable influence on certain classes of plants. All nitrogenous fertilizers, before being taken up by the plant, are converted in the soil into nitrates. This is done by bacteria, and this nitrification accounts for the fact that nitrate of soda acts more quickly than sulphate of ammonia, although crops treated with the latter overtake the other in a few weeks.

As the value of a fertilizer depends entirely upon the amounts of phosphoric acid in the different states, potash and nitrogen, many methods of chemical analysis have been tried. The separation of the different forms of calcium phosphate which may be present in a fertilizer is difficult, and therefore chemists, working on the same material, but by different methods, obtained variable results.

To obviate this difficulty an association of the official State chemists was formed, which meets each year to revise these analytical methods, so that two chemists may obtain uniform results.

That this will continue to be the case is evident when we consider the enormous exports of grain, tobacco, and cotton made by this country, and think how many pounds of potash and phosphoric acid are carried every year to Europe in these agricultural products. This export of these mineral matters from the soil, and the failure to return to the soil the sewage of our cities, containing the mineral constituents of all the foods consumed in them, will create a demand for artificial fertilizers which must grow as the new land in the country becomes scarcer.

MEETING 387.

Arbitration and Conciliation in Massachusetts.

BY HON. CHARLES H. WALCOTT.

The 387th meeting of the SOCIETY OF ARTS was held at the Institute, on Thursday, March 28th, at 8 P. M., Prof. Davis R. Dewey in the chair.

After the reading of the records of the previous meeting the chairman introduced Hon. Charles H. Walcott, of the State Board of Arbitration, who read a paper on "Arbitration and Conciliation in Massachusetts."

Mr. WALCOTT said: My purpose, this evening, is to lay before you some of the results accomplished in this State by arbitration and conciliation applied to labor questions, — with especial reference to the work of the State Board of Arbitration.

My attempt will be to speak from my own experience of the working men and working women of Massachusetts and of their employers, and to state somewhat briefly and simply what arbitration and conciliation have done in our State. It was not left to Massachusetts to discover or invent these methods of dealing with questions arising between employer and employed; but the forms and instru-

sachusetts through the astonishing rise and growth of the Knights of Labor. One of the aims of that order is declared to be "the enactment of laws providing for arbitration between employers and employed, and to enforce the decisions of the arbitrators;" also "to persuade employers to agree to arbitrate all differences which may arise between them and their employees, in order that the bonds of sympathy between them may be strengthened, and that strikes may be rendered unnecessary." In order to put in practice the principle here announced, joint boards of arbitration, as they were called, which were composed of equal numbers of manufacturers and workmen, were formed in some of the shoe manufacturing towns. There was, however, one essential element lacking in these boards. No umpire was provided for, and the result generally was that after repeated sessions and a great many indecisive votes, and when everybody was tired of wrangling, some one would change his vote, and so bring the matter to an end, but at the risk of being stigmatized as a renegade to the cause which he had been put forward to advocate. In these contests it was simply a question of physical endurance. The boards were composed, at the outset, of irreconcilable elements, and the decisions arrived at in the manner just described were not such as to commend themselves on their merits or to invite a repetition of the process.

There is no doubt, however, that these joint boards, by bringing employers and operatives together on terms of equality, were productive of much good, and the benefit would have been perceptibly greater had there been an umpire in the background ready to step in and decide questions in the event of a dead-lock. Herein is one of the principal merits of our present law, that not only does it provide for a fit representation of capital and labor, but it secures also a permanent umpire or referee. Without him you may have a well-devised system of checks and balances, but the more nearly perfect it is, by so much is action or decision rendered difficult or impossible.

Three years ago the General Court of Massachusetts enacted a law which, according to its title, was intended "to provide for a State Board of Arbitration for the settlement of differences between employers and their employees." The Governor was charged with the appointment of the Board, and it was provided that one member must be an employer or selected from some association representing employers of labor; another was required to be a member of some

decision is binding for the term of six months upon all who join in the proceedings; but either party may give to the other notice in writing that he does not intend to be bound by the decision at the expiration of sixty days from the giving of such notice. The term of six months has been found by experience to be convenient in arranging price-lists for manufacturers in this State, and is naturally suggested by the customs and movements of trade. Should the Board however fall into any serious error, and persist in it, the statute gives either party the opportunity to change the situation within sixty days by giving notice. Twice only has it been attempted to annul a decision in this manner. In both of these cases the recommendations of the Board continued in force, notwithstandfng the assaults made upon them.

But it is not a Board of Arbitration alone that is provided for by our law,—a tribunal that shall hold its sessions in due form, hear evidence and arguments, and give formal decisions. The functions of mediation and conciliation are added; and whenever in any manner it comes to the knowledge of the Board that a strike or lock-out is seriously threatened or has actually occurred in the Commonwealth, involving any person or corporation employing not less than twenty-five persons in the same general line of business, it is the duty of the Board to put itself in communication as soon as may be with the parties, "and endeavor by mediation to effect an amicable settlement." If a strike or lock-out has actually occurred, and the efforts of the Board to bring about an understanding prove fruitless, it may, if it deems such a course advisable, proceed to investigate the cause or causes of the controversy, without an application from any one, ascertain which party thereto is mainly responsible or blameworthy for its existence or continuance, and make and publish a report finding such cause or causes, and assigning such responsibility or blame. It was made the duty of the Board, after certain preliminaries, to "advise the respective parties what, if anything, ought to be done or submitted to by either or both to adjust" their disputes.

"Ought to be done or submitted to." The action of our legislators, on its face, presupposes a "higher law" than the Public Statutes, a broader equity than is recognized or administered by judge and jury. In point of fact, the matters considered by the Board have been chiefly questions of wages, hours of labor, the imposition

the Cape Ann granite companies called on us a short time ago to obtain a copy of the Board's list. A question had arisen between him and his men which he thought could be solved by reference to our list, and he had lost his copy of that decision. I asked him what he thought of it as a practical working list. He said that he had studied it carefully, and considered it the best price-list that had ever been made for cutting granite. This was a repetition of what we had heard in other quarters, but it was gratifying to hear from such authority that the list had stood the test of a practical application for more than a year, especially as the Master Builders' Association of Boston, and some workingmen even, took great pains to impress upon us, and upon the public through the newspapers, before we undertook that case, their conviction of the absurdity of three men who were not builders or stone-cutters attempting to make a price-list that would have any practical value.

Similar testimony has been received in abundance concerning prices recommended by the Board, from time to time, in the various departments of shoe-making and in other industries.

A year ago the capital city of our State was threatened with a general strike on the lines of one of the street railway corporations. The men employed in shoeing the horses struck for higher wages. The corporation refused to allow any advance, on the ground that the wages were already higher than were paid in other cities for this kind of work. New men were employed, the old hands became excited, and having no work to keep them busy, and perhaps not finding their homes altogether pleasant under the circumstances, passed the time in the saloons and at the corners of the streets. Being approached by the agent of the State Board, they spoke contemptuously of it, and said that poor men like them would have no standing with the Board when opposed by men of wealth and influence representing rich and powerful corporations. There was need for the exercise of tact and patience before these men could be induced to entertain a suggestion that they meet the Board and state their complaints. But when at length their committee appeared at the rooms of the Board, and entered upon a discussion of their grievances, in a frank, informal way, confidence soon took the place of distrust, and they went away to advise their associates to place their case in the hands of the Board and act under its advice. It should be remarked that no

It is safe to say that after this experience the officers of the corporation understood better than ever before the real disposition and wants of those workmen, and that the men brought with them from the discussion a greater respect for their employers, and with clearer ideas and more knowledge on the subject of wages than they had ever previously acquired. More valuable result even than this,— they realized as never before that the laws under which they lived were made with some reference to them and their needs and wants.

It may also be remarked that the settlement attained in this case through the instrumentality of the State Board was of practical benefit to the public, by removing all apprehension of a general strike on the railway in question, which would necessarily have caused great inconvenience to those who were accustomed to use its cars in traveling about the city.

The question is frequently asked in what proportion of cases decided by the Board are its recommendations accepted. The inquiry is a pertinent one, for all systems of government or methods of business must eventually stand or fall when judged by the practical results accomplished. I have recently reviewed the work of the Board in order to be able to report results as correctly as possible, and I find but one case in which either employer or employes failed to accept the decision of the Board in a case submitted jointly under the forms and with the agreements specified by law. In one instance a strike had occurred; the Board interposed, and prevailed upon the operatives, who were chiefly women, to return to work, being influenced thereto by the promises of the employer previously given that he would join in submitting the dispute to the decision of the Board. The employer actually signed the application and agreement in the presence of the Board and with full knowledge of all the facts.

The representatives of the operatives signed also, and the strikers returned to work. This result having been obtained the employer notified the Board that he had changed his mind, had sold his machines, and notified his employes that they were discharged, and that he should not take part any farther in the arbitration proceedings. The Board published a report of the facts, and stated in conclusion that in the opinion of the Board the action of the employer was a violation of his promise and written agreement. He accomplished his purpose, but I do not think that another manufacturer can

the name of the State, and assign the blame for the existence or continuance of the controversy.

However the advice offered may be received in particular cases, the Board never forgets that it is a board of conciliation as well as a tribunal empowered to judge and report.

In view of some recent events I will, with your permission, quote from the Board's annual report, which was submitted to the General Court last month.

Reference is there made to the obstacles to mediation in certain cases of difficulty, arising between an employer and a labor organization to which his employes for the time being do not belong. The same remarks are applicable when on the one side is a compact, well organized association of manufacturers, acting through their executive committee, and on the other a labor organization, acting also by its committee. The report says: —

"Such contests, although sometimes unavoidable, are generally productive of loss to both parties, of more or less disturbance of the public peace, and the mental and moral unsettling of many individuals. So long as the contest rages, with no desire on either side for a settlement of real or imagined grievances, there is obviously no place for a board like this. If the persons directly involved prefer to carry on a controversy in this manner, after being informed of a better way to effect a settlement, the public can only stand aloof and insist on preserving the peace. Even under circumstances like these the Board has always held itself in readiness to respond to any change of disposition that might show itself on either side, and so afford an opportunity for milder councils to bring order out of chaos. We can afford to wait, for the results of such cases invariably prove the superior practical value of arbitration and conciliation."

Whenever a strike or lock-out occurs, involving a considerable number of people, and the parties, one or both, prefer for any reason to neglect the means provided by law for the settlement of disputes of this character, the complaint is certain to come from some quarter that the power of the Board should be increased, and that there ought to be some way provided for compelling people to be reasonable and just in their relations to those with whom they are associated in productive industry. The mere suggestion that the Board should have power to enforce its decisions is in itself gratifying evidence that the

tions of Government concerning it, but a power behind Lord Granville. He and his colleagues would call it the power of public opinion."

If this be a true statement, as it no doubt is, of the influence which controls the relations of Great Britain with other countries, how infinitely more important it is that this influence be not neglected nor underrated in a country where "all men are born free and equal," and the principles of popular representative government are more firmly established.

MEETING 388.

Prison Reform.

BY PROF. FRANCIS WAYLAND.

The 388th meeting of the SOCIETY OF ARTS was held at the Institute, on Thursday, April 11th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, and the election of new members, the President introdueed Prof. Francis Wayland, of Yale College, who read a paper on "Prison Reform."

The speaker contended that the conceded increase of crime beyond the increase of population was due partly to the ignorance, partly to the indifference, and partly to the cowardice of the community. He illustrated this by the action of New York with reference to prison labor during the last quarter of a century, terminating in the passage of the "Yates bill," at a special session of the Legislature of that State, last July, which virtually condemned the entire prison population of the State to a condition of absolute idleness.

To the question, Has there been no improvement in our prisons for the last fifty years? Prof. Wayland replied by describing the deplorable condition of all the prisons one half century ago, when prisoners of all ages and all degrees of crime were indiscriminately

All this shows an inequality of attempted retribution which is almost universal. A distinguished criminal judge in this country, after thirty years' experience, recently exclaimed, "I am by no means certain that I have ever given a correct sentence!"

In the next place, arbitrary sentences are undesirable, first, as to the convict. If the true object of confining criminals is to protect society by secluding and reforming the offender, the only logical result is he should be confined till he is reformed. Nothing can be more absurd for the State to say to a confessedly unreformed convict, "You must be turned loose on society the moment the prison clock strikes twelve" on a given day; and yet, under our system of time sentences, a large majority of convicts are liberated who are avowed enemies of society, and intend to get their living by pillage and violence.

Again, time sentences are undesirable because of their effect on the criminal. If a man knows that his reformation has nothing to do with his release, a powerful motive for his reformation is withheld. The worst punishment which can be inflicted on a confirmed criminal is to keep him in confinement until his criminal impulses are removed. Such criminals prefer a long-time sentence at Sing-Sing to an indeterminate sentence to the Elmira Reformatory. If it is said that it is unsafe to intrust the power of discharge to prison managers, it may be replied that we are daily witnessing the same power exercised by experts in insanity, even where the insanity is homicidal, and we know that they often make mistakes which lead to fatal results, but nobody thinks of depriving them of this power.

A further step is indispensably necessary, viz., the permanent confinement of incorrigible offenders,—in other words, professional criminals, for whenever a man has demonstrated that he cannot safely be at large, he has forfeited his right to be at large.

Prof. Wayland stated further that the principle of the indeterminate sentence for first offences has been legalized in New York, Ohio, Pennsylvania, and Massachusetts, and that the permanent confinement of incorrigibles had been legalized in Ohio and Massachusetts, and their confinement for twenty-five years in Connecticut.

A long and interesting discussion followed the reading of the paper, after which the meeting was brought to a close by a vote of thanks to Prof. Wayland for his very interesting lecture.

All this early work was useful in stimulating scientific investigation and invention, and in gradually developing better forms of motors, and establishing the true principles on which they should be constructed. The commercial and practical results were nil.

Electricity is obtained from voltaic batteries by the consumption of the zinc plates. Zinc is too expensive a fuel to compete with coal.

In the meantime the dynamo-electric machine had been developed, and in 1864 Pacinotti, for the first time, enunciated the principle of the reversibility of this machine, which is the foundation of the modern method of transmitting electrical power to a distance. He described his machine as one that could be used to generate electricity on the application of motive power to the armature, or to produce motive power on connecting it with a suitable source of power.

A more sensational discovery of this principle of reversibility is related in connection with the Vienna Exposition, in 1873. Several Gramme dynamos were to be exhibited. A workman, seeing a pair of loose wires near one of the machines, connected them to the proper binding posts, and, to his astonishment, the armature immediately began to revolve. Upon investigation it was found that the other ends of the wires were connected with a machine in operation, the source of power being a steam engine. Whether the result was attained accidentally or purposely, it was undoubtedly the first instance of the transmission of power to a distance by means of an electrical current generated by a dynamo-electric machine. The future history of the world will be greatly affected by this discovery.

The dynamo or generator and the motor are theoretically the same. If a steam engine be belted to an armature pulley, and the armature pulley be made to revolve, a current of electricity is passed through the machine, the armature is made to revolve, and by belting to the armature pulley mechanical power is available. In this way one dynamo will convert the mechanical power of the steam engine into electrical power, and the electrical power may be carried through the wires to the second dynamo, perhaps five miles away, where it is reconverted into mechanical power, and so made available for any desired purpose. The second dynamo is called the motor, and differs from the first, not in principle, but only in details which make it better suited for its special work. In this way we do away with the

brushes on the motor, thence to a segment of the commutator, and so to the armature coils. The wire with a current flowing through it in a given direction is repelled by one pole and attracted by the other. The powers of attraction and repulsion compel the armature to move; it revolves, and we have mechanical energy. We gear the armature to the car axle, and we have motion.

There are two general methods of using electricity for the propulsion of street cars: —

1. The direct method, by conductors extending from the dynamo along the track.

2. The indirect method, by the use of storage batteries, secondary batteries or accumulators.

In the direct method the conductors may be overhead, under ground, or on the surface.

In the conduit system the conductors are placed in a conduit between the rails or between the tracks. The wires must be bare, and yet must be thoroughly insulated from the ground,— a condition very difficult to obtain under such circumstances. A slot about five-eighths of an inch wide gives access to the conductors by means of a contact plow; but, unfortunately, also permits the flow of water, slush, mud, etc., into the conduit. The present stage of the art in this respect is illustrated by the conduit on Boylston Street, in front of this building. It is not a success.

The overhead wire is suspended from poles by brackets or from cross wires, which span the street between poles on either side. When the street is of sufficient width, poles are placed in the center of the street between the two tracks, with bracket arms carrying the conducting wires. These poles are placed about 125 feet apart, and from actual experience are found to present little or no obstruction to traffic. The wires may be single or double. When single wire is used, the rails are utilized for the return current. When two wires are used, one wire carries the outgoing and one the return current. Contact is obtained with the wire by an over-running or an under-running trolley. The over-running trolley is a light carriage with one or more wheels resting on the wire. A flexible conductor carries the current down to the car. The trolley is pulled along by the flexible conductor. The objections to the over-running trolley are that it is difficult to keep the trolley on the wire, it is difficult to replace the

The steam engine is not an efficient machine. If we can utilize 15 per cent of the units of energy stored in the coal, we are fortunate. In other words, we must expect a loss of 85 per cent of the heat units in converting the other 15 into mechanical power.

The dynamo-electric machine, on the other hand, possesses a high degree of efficiency. No good generator runs below 92 per cent efficiency. The loss in the line depends upon the amount of copper used in proportion to the current to be carried. The size of the conductor is generally calculated for a loss of 10 per cent. The efficiency of the motor, under favorable circumstances, has been shown to be but little below the generator,— in actual tests running as high as 91½ per cent. In practice it would not probably be taken higher than 85 per cent. Starting, then, with 100 horse power in the steam engine, we lose 8 per cent in the dynamo in converting the mechanical into electrical energy. The output of the generator is then 92 horse power. In the line we lose 10 per cent, and deliver 82.8 horse power to the motor. Here we lose 15 per cent, and on the final reconversion into mechanical energy on the car, we have 70.4 horse power out of the original 100 horse power. By no other known method could this power be transported to such a distance with so little loss.

2. Economy: —

This is, perhaps, a quality which appeals more directly to the railway official than any other. What will it cost? An electric railway connects Omaha with Council Bluffs, across the new bridge. I am credibly informed that to run twenty cars per day they consume five tons of slack, for which they pay $1.14 per ton. This is 28½ cents per day for fuel. These cars are scheduled at fifteen miles per hour, and the average daily mileage, per car, is over 100 miles. Where natural gas or water is available fuel may be even cheaper. On many different roads, from numerous measurements, it has been found that where the grades are slight the power required averages from 5 to 8 horse power per car. The consumption of fuel varies from 3 to 6 pounds of coal per horse power, according to the style of engine and its more or less economical operation. Of course, a road operating only one or two cars would show abnormal results in every way, and these averages are only true of roads operating a number of cars, ten or more. The wear and tear on the generating plant does not exceed 3 per cent. The depreciation on line work does not exceed

cause whatever, nor has the car failed to run on time. No one can look at the daily record of this car, under conditions which would prevent horse car work, and doubt the reliability of electrical apparatus. On the Cambridge line of the West End Road the conditions are uuusually bad. During the month ending April 19th the schedule called for 5912 round car trips. Of these the electrical cars failed to make just four trips.

As the railway employes become more familiar with electrical apparatus, and learn more of the details of handling the cars, accidents, mishaps, and lost trips will grow fewer and fewer; but the records above referred to suffice to prove the reliability of the electric motor.

Storage battery cars are in operation on one road in the United States,— the Fourth Avenue line in New York city. Conduits have been built in several places. In San Jose, Cal., and in Denver, Colorado, they were complete failures. In Alleghany city, Penn., the conduit has operated with considerable success. In Boston it has not been a marked success. There are at the present time over one hundred roads in operation, or under contract, where the overhead wire system is to be employed. From this we may infer that the storage battery and conduit are yet in an experimental stage, while the overhead wire is a pronounced and demonstrated success. What the future of storage batteries and conduits may be no one can tell; but we all hope that the difficulties encountered may be overcome, as the storage system is unquestionably the ideal system.

The objections usually urged against the overhead wires are:—

1. They are dangerous, as they carry death-dealing currents.
2. They are eye-sores.
3. The poles obstruct the street.
4. They are in the way in case of fires.

Now, the railway wire should not be confounded with other electric wires. Arc and incandescent wires, telegraph and telephone wires, have simply to carry the current from the point where it is generated to the point where it is to be used; and so far as this purpose is concerned, they may be above ground or under ground. The railway wire, on the other hand, must have current taken from it every differential of an inch, from one end to the other. The wire must be bare, that the trolley wheel may be in constant contact. To

these mains is 12 inches. If they are closed at the outer ends we may fill the overhead main, but after that no water can flow until we connect the two pipes. Now we will put in a one-inch pipe, connecting the upper main with the lower main, say 1000 feet from the pump or generator. A certain amount of water will flow through the connecting pipe, which amount depends upon its size — one inch — and upon the pressure of the water in the upper main. From the generator to the one-inch connecting pipe the same amount of water flows in the upper main as flows down through the connection,— no more and no less. Beyond the connecting pipe no water is flowing in the upper main.

Now we will put in a second connecting pipe 1000 feet beyond the first. For the first thousand feet we have twice as much water flowing as before. Half of it goes down through the first pipe. It is the same with every additional connecting pipe we put in until we reach the capacity of the upper main or the capacity of the generator to force water through it. By increasing the pressure we know that we could force more water through the one-inch connecting pipe, and so long as the pressure remains the same the quantity flowing through the inch pipe will be the same, whether the upper main be 12 inches, 12 feet, or 1000 feet in diameter.

The analogy to electric railway work is close. Electricity takes the place of the water, and the connecting pipes are electric cars, or it may be some unfortunate man placed where he ought not to be. He is only an inch pipe, however, and the pressure (500 volts) can only drive so much electricity through him.

The current for railway work has been fixed at 500 volts, as this is well within the safe limits. A shock from 500 volts is unpleasant, but not dangerous. No man, woman, or child has ever been killed, or even seriously injured, by a 500 volt current. The United States Senate had this question before them last summer. After a thorough investigation the District Committee unanimously reported that a 500 volt current is not dangerous. If there was any real question of its being dangerous we would use 400 volts or 300 volts. The objection to this, however, is that by reducing the voltage we must correspondingly increase the quantity in order to retain the same horse power, and an increase in quantity (amperes) means an increase in the size of the overhead wires, which is objectionable.

Charles J. Van Depoele and Leo Daft were the pioneers in the modern electric railway work in this country.

The first roads were built in 1884–85. The new motive power was, however, viewed with suspicion, and progress was slow until the Richmond road was built by the Sprague Company, in 1887–88. This road did much to popularize electric motors. The rapidity with which the horse is now going is shown by the growth of the railway business of the Thomson-Houston Electric Company, one of the several companies working in this field. In the spring of 1888 this company purchased the patents of the Van Depoele Electric Company, of Chicago. At that time there were some fourteen roads operating under the Van Depoele electric system. The first Thomson-Houston car was started at Crescent Beach, Mass., July 4, 1888. On the 1st of April, 1889, in less than nine months, there were 18 roads with 104 motor cars in operation, and 33 roads with 210 motor cars, under contract.

The reasons for this rapid growth are not difficult to ascertain.

The Americans are essentially a fast people. We live fast, and, unfortunately, we die fast. But as long as we do live, we go. Any time-saving device is gladly welcomed, and at once becomes popular. The limit of speed with horse cars is about 8 miles per hour. With electricity, the only limit is what we may fix as a safe speed. If horse cars are delayed, there is little or no chance of making up lost time. The reverse is true of electricity. With electricity we have rapid transit, and we can obtain it in a very simple and not too expensive way. Electric motor cars do not smoke or give off noxious gases, or make disagreeable noises. It is not necessary to run them in the air or under the ground, though they would run well in either position. They are safe, clean, fast, and reliable. They do not keep the street in an unclean and unhealthy condition. They do not take up as much of the street as do horse cars, for they have no horses. They are brilliantly lighted at night.

All of these qualities appeal to the public, and the verdict everywhere is favorable to electricity. The United States Senate and House of Representatives, in reporting on a proposed extension of the Washington road, said: "It is undoubtedly the best electric railway in the United States, and beyond comparison superior to any horse railway."

pay the current rate of wages, and the question then arises if he cannot make it still more profitable for his workmen and himself by dividing among them a portion of the profits he realizes. Will a proposition of this kind, made by a manufacturer to his men, have the effect of increasing zeal, economy, and carefulness among them to such an extent that his own share of the profits will be at least as large as the whole was before, or even larger? Experience, not theory, must be called upon to answer this question. If in a considerable number of thorough trials of the principles of profit sharing it results in an increase of the whole profits of the business, and the workman's bonus is not taken out of the average profit, but is an addition, then profit sharing is good sense and good business. If, on the contrary, under the system of a division of profits between master and man, the men are no more zealous, economical, and careful than under the simple wages system, if thus the resulting profits, so far as labor is concerned, are not greater than before, then profit sharing is obviously poor business and nonsense. Let us, then, at the outset, dismiss theorizing about a wages-fund or other chimeras, and let us equally dismiss the confident prophecies of business men or others who know just what workmen will do if offered a share in the profits of business. Prophecy as an avocation is properly held in very little respect today. For my own part I have as little regard for it when coming from the lips of a business man, about matters concerning which he is distingushed by a plentiful lack of knowledge, as when it falls from one of my clerical brethren who are following Mr. Edward Bellamy's will-o'-the-wisp, and are not only "looking backward," but are also looking down upon experience. The scientific temper is equally averse to the Philistinism of the business man who reads only his partisan daily paper, and the enthusiasm of the hasty reformers who propose to inaugurate their kingdom of heaven tomorrow or next year. Always "the next step," as Rev. Mr. Savage says, is the practically important matter. Because profit sharing is such a feasible next step, I commend it to men whose action must be ruled by the facts of the existing social order.

It is disorder, to be sure, which we see in the industrial world today. When the United States Commissioner of Labor gives us the figures in detail, to show that in this country there were in the six years, 1881–86, 3902 strikes, involving 22,304 establishments, and

according to the nature of the particular business. Now, what has been the result in the great majority of recorded instances where such an offer as this has been made? The effect has usually been that the employe, in the course of a year or two, if not sooner, begins to show some of the qualities of a man who has an eye for profit as well as for wages. If the employer points out to his men, as he should, the numerous items of waste and loss due to the lack of care on the part of the workman, they become anxious to save, because such saving is so much added to their bonus. They are more careful in the handling of the tools and machinery. They look after each other more sharply because of a common interest in securing good work. They realize more and more, as time goes on, that they are in a real partnership with their employers, and that they should work in some degree as if working for themselves. It is a very different thing from that wearisome platitude about the interests of labor and capital being identical. When the interest of the men in a particular shop is thus plainly brought into accord with the interest of their individual employer, strikes and other labor difficulties tend to disappear thoroughly from such an establishment.

While the future undoubtedly holds in it other labor problems which must be met and solved, the advocates of profit sharing may properly claim that of all proposed remedies for labor troubles it is the most practicable, that it has excellent credentials from the numerous firms that have tried it for a term of years, and that its obvious merits are such that a very wide and very thorough trial of it may reasonably be asked in order to determine its practical limitation. No sensible person claims that any one method of relief for labor troubles is universally applicable. Notwithstanding the repeated disclaimers I have made in my volume to the effect that "any attempt at a panacea" for existing discontent in the industrial world "is plainly irrational," a friendly critic in *The Nation* easily sees that I have not rid my mind "of the notion that it is in this way the discontent of the laboring class is to be met." Myself a professional reviewer of books for years, I know how hard it is to convince a reviewer that he is not better acquainted with the mind of an author than the innocent author himself. Even when we reviewers have to follow the African traveling custom of which Prof. Huxley somewhere speaks, and cut our noon-day steak from the ox on which

to produce its educational effect. I am neither a prophet nor the son of a prophet. I will not undertake, therefore, to predict the number of firms which here in the United States will be practicing profit sharing ten years from now. It would be, however, a singular phenomenon if, with such a recommendation from experience as its history shows, and with such an amount of favorable opinion as I have discovered from the able men whose positions make them impartial students of labor difficulties, profit sharing should experience an arrest of development, and go no further. The one need of the existing situation is information concerning the matter that can be relied upon. I have too much confidence in the shrewdness and the fundamental fair-mindedness of American employers of labor to suppose that they are all in the "pooh-pooh" stage of development themselves with respect to suggested modification of the wages system, or that the majority of them will remain in it. Men, indeed, easily forget how recent a phenomenon this system is in the development of industry. We are too apt, here as elsewhere, to consider our inherited habits to be the eternal laws for the universe. The wages system is not exempt from the force at work elsewhere adapting old institutions to the new needs of a growing humanity.

Profit sharing will not, at present, please the Malthusian; it will not satisfy the followers of Mr. Henry George, who declares that the "natural wages of the laborer is the product of his labor," and that "less than this it is a sin that he should be compelled to accept," the manager and the capitalist being considered unworthy of attention from their school. A simple share in profits will not seem of account in the eyes of the ardent minds who pine for nationalization of land and industry. But slow is "the unreasoning progress of the world," in Wordsworth's phrase; a little less slow is its reasoning progress, as, guided by experience, and determined to keep to the substantial world of fact, we put foot before foot, chiefly concerned that our next step shall be both forward and permanent. Such a step, and it is a long one for any large section of the industrial world, with its natural and proper conservatism, is the extension of the principle of industrial partnership to the highest grades of workingmen. The movement toward profit sharing has all the force of reasoned moderation behind it. That force becomes more confident of the rightness of its course as the body of favorable fact increases. The objection to a

and utilized the gas both for heating and lighting purposes. Experiments were not begun, however, in Europe until the latter half of the eighteenth century, with gas from coal; and in 1793 Murdock, an Englishman, erected the first gas works. About the same time gas from wood was used in a very small and experimental way in France, and oil gas in 1815. Gas was first used for street illumination in 1812 in London, and in 1815 in Paris. These dates are interesting, showing that, although a new country, we were soon to follow, for in Baltimore, though the first attempt was not successful, it was made so in 1821, in New York in 1827, and in Boston in 1822, or only sixty-seven years.

We have already grown discontented with it as an illuminant, as the public has been educated to a higher standard by the competition between electricity and gas light,—and this competition has and will lead to improvements in both. The electric light, by its steadiness, freedom from heat, convenience, and purity of color, has made a demand for similar advantages and qualities in the use of gas as an illuminant. Up to within a few years the work done has been in the line of improvement in the economy of manufacture and purity of the gas, increasing its illuminating quality by superheating or enriching with hydrocarbons, and regulating by governors, etc. Now attention is directed to obtaining from the gas its greatest heat, and using this energy to render non-combustible bodies incandescent, or properly lighting by incandescence.

The illumination from gas, as ordinarily used, proceeds from the liberation of the solid particles of carbon from the olefiant gas and rich hydrocarbons by the heat caused by the oxidation of the hydrogen at points in the flame when the supply of oxygen is not sufficient for both hydrogen and carbon, and by the combustion of the carbonic oxide. This heat renders these carbon particles highly luminous. These particles are themselves oxidized, and generate heat or energy which is lost. This is saved when the gas is completely oxidized, or converted into a heating flame, and this heat applied directly to an incandescent body. The lower the heat required to render this body incandescent the greater will be the economy in the use of gas and greater the amount of light produced.

That the energy is lost is very easily demonstrated. If the combustion of the gas is assisted, and rendered perfect by the aid of

required for gas; facility of breakage or derangement must be impossible; and the duration of the lighting medium must be so great that the cost of renewals (which must be in any case insignificant) should be inappreciable.

5th. The consumption of gas must not be increased, but, on the contrary, a very marked saving, either in consumption or its equivalent in the increased light, must be secured.

6th. The combustion must be more perfect than of the ordinary gas burner, in order to reduce to a marked degree the objectionable and destructive effects of gas consumed in dwellings, *i. e.*, less heat, less vitiation of the atmosphere of the room, less smoke, less soot and unconsumed gas.

7th. The light obtained must remain constant, and not deteriorate with the use of the medium.

In going over the field to see what has been done we find, in 1876, J. D. Palmer, of London, filed a specification for the combination of a finely-woven wire-gauze cap of platinum, iridium, or other refractory metal, with a base through which atmospheric air and gas at ordinary pressure were admitted. These, mixing within the cap, produce on ignition sufficient heat to incandesce the gauze, the effect being increased by the addition of a central metal rod that was brought to and maintained at a very high temperature by the burning gas.

Reckenzaum and Redfield, in 1882, patented an apparatus for producing gas from a mixture of air and hydrocarbon, and a burner formed of a coil or other form of platinum or iridium gauze, to which the gas is led.

Thomas Cooper, of England, 1883, has also a form of lamp as above.

W. B. Wicken, of London, filed a specification, in 1883, for a regenerating gas lamp, in which the source of light was to be a spherical mass of loosely-compacted platinum wires suspended over the heat from a Bunsen burner.

Victor Popp, of Paris, in 1882 and 1884, secured two patents for wire-gauze incandescing cones.

J. S. Williams, of New Jersey, in 1882 secured a patent in England for what he terms a thermo candle. He impregnates or coats a gauze of any suitable material as a base or form for the deposition of metal or metal alloy, thereby obtaining an extended open surface for

"For the combustion of gas in this manner (*i. e.*, to obtain the greatest heat) the air on its way to the flame is caused to pass through a tube of refractory material, which is heated to a high temperature by jets of the gas playing against its external surface; and, in order that the air may be more thoroughly heated, the interior of the tube is divided by partitions having apertures through which the air has to pass in a zigsag manner, being subdivided into numerous streams directed against the heated sides of the tube. From the tube the heated air issues through small apertures and mingles with the ignited gas, producing a flame of intense heat, which, directed on refractory material, such as lime, causes incandesence."

These have been introduced into Paris to a very limited extent. The claim is one cubic foot of gas for five candles. A writer in a French journal, *L'Eclairage dans la Ville et dans la Maison*, states that the life of the basket is from twelve to fifteen hours.

The high price of this burner, $6.00, and baskets for renewals twenty cents, places this among the luxuries of incandescent gas burners. The claim of five candles per foot of gas I believe is too high, from a series of tests on several of these burners made in this country, with a consumption of 5¾ feet per hour, an efficiency of only 3½ candles per foot, as a maximum was obtained, although they gave a fair light for fifty hours of continuous burning. This manner of burning is rather in their favor, as it prevents any danger of disintegrating by the magnesia or composition of the basket absorbing moisture and carbonic acid from the air, and thus slaking.

During the tests referred to the small holes in the heated earthenware became clogged with carbon deposited from the gas being decomposed before it could become oxidized by the air. This caused even more trouble than the burning out of the mantles, and ultimately terminated the experiment.

Chas. M. Lungren, of New York, patented in 1888 an incandescent burner, in which he uses a reticulated cone or basket, similar to Clamond's, made of magnesia, and supported over a form of Bunsen burner.

The heat required to render such a large quantity of material incandescent, as is necessitated by the construction of the hood or basket, prevents this form from ever becoming successful. The hoods must, in order to become incandescent, consist largely of magnesia,

incandescent material is suspended, has been placed over the Bunsen burner, and the lamp is ready for lighting. Inside of the brass gallery in the cup covered by the lower part of the mantle, and into which the upper end of the Bunsen enters, are placed two disks of wire gauze to prevent the Bunsen burner from "flashing back," or, more properly, the gas from igniting in the tube where it first enters and becomes mixed with the air.

Figure 3 represents a mantle in its first stage of manufacture, and consists of a tubular piece of webbing knitted by machinery, from the best quality of cotton thread. This is important for the reason that the mantle, when the cotton is burned out, will be an exact duplicate in oxides of the rare earths. Not only will the loops and twisting of the thread be reproduced, but even the fuz or individual fiber; and to show how refractory these earths are, these minute fibers exhibit no signs of fusing or volatilizing, even after hundreds of hours of burning. A strong and well-made thread, for the above reasons, it can be easily seen, will be required for these mantles. It gives to the completed mantle the mechanical strength of construction it possesses itself. The webbing, after being cut into proper lengths, is thoroughly washed, dried, and dipped into a solution of the rare earths, and again dried. A small piece of platinum wire is sewed into the upper end, by which it is secured to the iron wire support which holds it in place over the flame. After attaching it to the support it is formed into the desired shape of the finished mantle or hood, and the cotton burned out over a Bunsen flame. Any wrinkles or imperfections in shape are at this stage pressed out by means of a steatite pencil, for it is now pliable, and can be easily formed, stretched, etc. It is now as it is shown in figure 4, ready for use; or, if to be shipped, it is dipped into a solution of shellac or similar material to prevent breakage. This burns off the instant the lamp is first lighted.

The mantle in ordinary use for coal gas is $\frac{8}{10}''$ in diameter by four inches long, or containing nearly twelve square inches of surface. Yet it weighs but six grains, one half grain to the square inch, or a pound of the rare oxides used in its construction would cover 14,000 square inches of surface. This clearly shows how little material has to be heated to produce incandescence. This is the great point of success in this system and where the energy of the gas is utilized. Yet these oxides, even while in such an attenuated form, are practi-

their soluble salts may be used, if the acid can be driven off by heat. The nitrate is well adapted, as it also assists in burning the cotton.

In the mantle zirconium and thorium oxides may be regarded as the support or skeleton, and the other rare oxides added for the purpose of producing incandescence, to change the quality of the light, or to add additional strength.

Absolute cleanliness must be observed in every detail in the manufacture of the fluid and mantles. In the fluid the faintest traces of elements foreign to it can readily be preserved in the hood, and its manufacture requires the most careful supervision. The process is a long one, as it requires from six months to a year to bring the ores into the form of pure and finished salts, ready for solution. This fluid, as well as the mantles, are now being manufactured in this country, at Gloucester City, N. J., where the company have extensive works.

Working these rare minerals, semarskite, cerite, zircon, monazite, etc., in such large quantities, has led to many discoveries, and to the separation of new elements yet to be named, their properties investigated, and the one separated from the other. At present they hold the unique position of being by-products.

Dr. Auer von Welsbach, in his researches, succeeded in separating didymium, a long-discovered and so-called element, into two elements, which he named praseodymium and neodymium. The latter is largely used in the manufacture of the mantle.

The incandescent light produced from these rare oxides possesses great actinic power. Mr. George G. Rockwood, photographer, of New York, succeeds in taking excellent portraits in from four to ten seconds, in an ordinary gallery, with twenty-five small-sized burners, equal in every respect to those taken by daylight.

Regarding the practical application of the Welsbach lamp it has now been so perfected that it can be used with coal, water, fuel, gasoline, and natural gas with not only good but remarkable results, as to steadiness, color, and quantity of light. The average life of the mantle, which can readily be renewed, in ordinary use, is about four hundred hours, or three to four months. The color can be varied to any degree, from pure white to an intense orange.

It can be readily attached to any existing gas fixture. The small quantity of gas consumed throws off but little heat. In fact, the

1.01	2.25	25.5	10.8	DR. HENRY MORTON, President Stevens Institute of Technology, New Jersey.
0.90	2.10	25.5	12.1	
0.80	1.95	24.0	12.3	
1.06	2.30	23.0	10.0	
0.85	2.45	24.0	9.8	
0.95	2.75	33.0	12.0	
0.80	2.47	29.0	11.7	
.60	2.14	17.01	7.94	L. CALVERT FORD, U. S. Inspector of Gas and Meters for the District of Columbia, Washington.
.70	2.19	16.42	8.41	
.90	2.76	22.65	8.14	
1.00	2.82	24.11	8.54	
1.30	2.92	24.95	8.54	
.60	2.05	18.96	9.25	DR. WILLIAM WALLACE, F.R.S.E., F.I.C., F.C.S., Public Analyst, and Gas Examiner for the City of Glascow.
.70	2.20	21.00	9.55	
.80	2.42	[illegible]	9.05	
.60	1.95	19.02	9.75	
.70	2.10	20.75	9.88	
.80	2.30	21.19	9.21	
.90	1.85	18.40	9.94	
1.10	2.02	21.60	10.69	
1.30	2.90	22.60	10.27	
.90	2.20	[illegible]	8.1	CONRAD W. COOKE, London.
.90	2.40	17.5	7.3	
.90	2.55	[illegible]	7.6	
1.25	2.36	20.0	8.5	
1.25	2.25	19.0	8.4	

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

ABSTRACT OF THE

Proceedings of the Society of Arts,

WITH LIST OF OFFICERS AND MEMBERS,

FOR THE TWENTY-EIGHTH YEAR.

1889–1890.

MEETINGS 392 TO 404 INCLUSIVE.

BOSTON:
W. J. SCHOFIELD, PRINTER, 105 SUMMER STREET.
1890.

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1889–90.

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LINUS FAUNCE.

1890–91.

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CONTENTS.

NOTICE.

The SOCIETY OF ARTS, established in conformity with the plan of the Massachusetts Institute of Technology, as set forth in the act of incorporation, April, 1861, held its first meeting on April 8, 1862.

The objects of the Society are to awaken and maintain an active interest in the practical sciences. and to aid generally in their advancement in connection with arts, agriculture, manufactures, and commerce.

Regular meetings are held semi-monthly from October to May, inclusive, in the Institute Building; and at each meeting communications are presented on some subjects germane to the objects of the Society, as stated above.

The present volume contains the abstracts of the communications made during the year ending October 1, 1890, most of the business portions of the records being omitted.

The thanks of the Society are due to Capt. A. H. Russell, for the loan of the electrotypes used in illustrating his paper on Magazine Guns; to Col. E. H. Hewins for those illustrating his paper on Storage Batteries; to the Electrical Engineer for those illustrating Prof. Thomson's paper on "Experiments with Alternating Currents"; to the Engineering and Building Record for those illustrating Mr. Woodbridge's paper on The Heating and Ventilating of the new Engineering Building.

For the opinions advanced by any of the speakers the Society assumes no responsibility.

LINUS FAUNCE,
SECRETARY.

BOSTON, SEPT., 1890.

PROCEEDINGS OF THE SOCIETY OF ARTS

FOR THE TWENTY-EIGHTH YEAR.

MEETING 392.

*Biological Water Analysis.**

BY PROF. W. T. SEDGWICK.

The 392nd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, October 10, 1889, at 8 P.M., Hon. J. A. Dresser in the chair.

After the reading of the records of the previous meeting, the Chairman introduced Prof. W. T. Sedgwick, of the Institute, who read a paper on "Biological Water Analysis."

Prof. SEDGWICK said: A biological analysis of water, strictly speaking, is an impossibility. Water may be analyzed chemically and resolved into its components, hydrogen and oxygen, but a biological analysis of water is an impossibility, because water is absolutely lifeless and inorganic. By a chemical "water analysis," however, the chemist does not usually mean the analysis of a portion of pure water, but only a chemical examination of the substances dissolved in, or carried by, the water. In precisely the same way a biological "water analysis" is understood to be simply *an examination of the organisms present in a particular portion of water.*

The biological analysis of a water must deal with all the organisms which can be detected therein; but inasmuch as the coarser water-dwellers — the fishes, the frogs, the snails, the water-weed, etc. — are seldom collected in a sample for water analysis, there are usually present only the very small, and often quite invisible, organ-

* Revised from an address published in the Journal N. E. Water Works Association, September, 1889.

MICROÖRGANISMS. Organisms, either plants or animals, too small to be studied with the naked eye.	MICROSCOPICAL ORGANISMS. Not requiring special "cultures." Easily studied with the microscope. Microscopic in size, or barely visible to the naked eye. Plants or animals.
	BACTERIAL ORGANISMS. Requiring special cultures for their satisfactory study. Difficult of study with the microscope, because almost sub-microscopic in size. Plants.

The bacterial microörganisms include the bacteria, as well as some yeasts and moulds. The microscopical microörganisms include a great variety of animals, such as minute entomostraca, like Cyclops and the water flea; various worms and wheel-animalcules; sponges and the fresh-water Hydra; infusoria, rhizopods, and such like; and among the plants, the diatoms, algæ, fungi (excepting those already mentioned), and the so-called "blue-green algæ." Beside the bacteria these forms are mostly of giant size, and hence may be seen and studied with comparative ease by the aid of the microscope alone.

I am the more anxious to urge upon your attention the microscopical microörganisms since it is with them that some of the more recent progress has been made in the biological analysis of water. Furthermore, it is in this field, in all probability, that some of the most interesting developments of the next year or two will be found. These are the organisms that often pave the way for the bacteria in water, and possibly therefore for the germs of disease. These are the organisms which are, in large measure, the source in water of the "organic nitrogen" (or albuminoid ammonia) of the chemists; the organisms, responsible in large measure, for odors, tastes, and turbidities in waters, either directly by their own activity, or indirectly by amassing organic matter, and eventually surrendering it as putrescible food for the more destructive bacterial organisms.

As long ago as 1850 Dr. Arthur Hill Hassall made a microscopical examination of the water supply of London, perhaps the first ever scientifically made anywhere, and, in discussing his results, wrote afterwards as follows: * "The deleterious properties of impure water depend, for the most part, on their *organic impurities.*

* "Food and its Adulterations," p. 55, London, 1885.

resting satisfied; while biologists, on the other, instead of seeking a simple explanation for the presence or absence of organisms, or endeavoring to learn their chemical significance, have too often dissipated their energies in struggles to classify those organisms which they could name, and to name those which they could not classify. Doubtless, also, the rise of bacteriolgy, soon after the appearance of Cohn's paper, with the intense interest which it aroused, did much to distract attention from the microscopical microörganisms, and to fix it upon the bacterial. But even concerning the bacterial microörganisms interest has been thus far principally medical. The discovery that infectious diseases may be propagated in drinking-water caused general alarm. Most bacteria, however, are not disease germs; and yet they are scarcely less interesting on that account, for by their presence they always signify something, and in their absence are hardly less conspicious. Bacteria are fungi; that is, they are not green with chlorophyll, and, consequently, since they cannot build up food for themselves from mineral matters, as they might do if they had chlorophyll, they are obliged to live upon ready-made foods. If, then, a drinking-water contains bacteria, living and thriving, there is no escape from the conclusion that there is or has lately been ready-made food in that water. Well waters usually contain few bacteria; and this we would expect from their poverty in ready-made food,— which is only another name for some kinds of organic matter. River waters usually contain numerous bacteria, and ready-made food is generally there in the shape of organic matter of one kind or another. Now, it is precisely this ready-made food that the bacteria must live upon, and which they oxidize eventually to mineral matters, that the larger, microscopical, microörganisms abundantly produce. Moreover, the microscopical organisms not only pave the way for bacteria, they often themselves become serious nuisances in reservoirs and lakes used as water supplies, by giving rise to extensive "growths" which, either during their development generate directly odors and tastes, or during their decay support a prolific host of bacteria, thus generating indirectly turbidities or odors which make the water disgusting and unfit to drink. It is somewhat remarkable that while the importance of these organisms and of their accurate study has long been recognized, no satisfactory method has hitherto been devised for their study. Up to the present time the best methods have made no pretensions to be

usually counted and the sum obtained is multiplied by 50, thus giving the amount in 1,000 squares, *i. e.*, upon the whole plate. The sand may, after some practice, be easily neglected, and does not interfere. In the choice of the special arrangement of ruled lines, and especially in the patient construction of several finished plates by means of the dividing engine, I have been very greatly aided by my friend and former pupil, Miss C. A. Woodman.

From my results it appears that a teaspoonful of drinking-water often contains from twelve to fifty microscopical microörganisms, and may sometimes contain thousands. Indeed, they often far outnumber the bacteria, as, for instance, in the Newton reservoir, where, with 1,602 microscopical, only 6 bacterial microörganisms were found in a cubic centimeter of water. In this connection I may mention a curious result which was disclosed by an application of the method to the Newton water supply. Water was drawn from the tap in the railway station at Newton Highlands every morning, excepting on Sunday. On Mondays the numbers were observed to be very high, reaching into the thousands per cubic centimeter, while during the rest of the week they barely reached hundreds. Inquiry disclosed the fact that on week days water is pumped from the filter-basin directly into the service-pipes. On Sundays the pumps are not run, and the pipes are filled from the reservoir. The reservoir water, however, is much less pure than that drawn directly from the filter-basin; and this fact became immediately and strikingly apparent by the examination of a sample collected early on Monday morning, before the pipes had been filled from the filter-basin.

It may fairly be claimed, I think, that we now possess a simple, convenient, and effective method for the enumeration and study of the microscopical microörganisms. There is no doubt that this is a step forward in the biological analysis of water, which must henceforward include microscopical as well as bacterial examinations.

As the result of his own studies upon drinking-waters, Cohn, in the paper already referred to, laid down certain generalizations that do not seem to have attracted the attention which, if true, they should have received. For example (*l. c.*, p. 113): "We may divide the organisms in drinking-water [wells] into three categories, which correspond to different degrees of purity of the water:—

(and, above all, upon a single analysis) is no longer a complete scientific opinion. A water analysis henceforwards must be three sided, viz., chemical, bacterial, and microscopical; and even then the conditions of the origin and of the neighborhood of the source of the water must be included as factors of equal importance. The standard of water analysis has of late appreciably risen, and reports of "water analyses," if they are to fullfil the conditions imposed by the most recent progress, must include three different examinations, as follows: —

I. ENVIRONMENTAL, *i. e.*, a more or less complete study of the source of the water, together with observations of the surroundings, and investigation of specimens unquestionably normal, from the vicinity.

II. CHEMICAL, *i. e.*, the usual chemical analysis, with special attention, however, to the state of the nitrogen present.

III. BIOLOGICAL, *i. e.* (1), *Microscopical*, viz., a determination of the number, the species, and, as far as possible, the conditions of the larger microörganisms present; as well as of the masses of *débris*, etc.

(2) *Bacterial*, viz., a determination of the number, and, as far as possible, of the species of the living bacterial organisms present.

MEETING 393.

The History and Theory of Cohesive Construction as Applied Especially to the Timbrel Vault.

BY MR. RAPHAEL GUASTAVINO.

The 393rd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, October 24th, at 8 P. M., President Walker in the chair.

obtain new practical systems of construction, knowing the fact that the improvement of the material required a change and improvement in the construction, but their noble aspirations were restricted, having no facilities, and it was necessary to satisfy themselves by recommending the theories of Vicard, about the use of cements, and other applications well founded.

Nothing was done about investigating these structures to which I have referred, and no coefficients were derived. This only can be obtained when we can depend upon the materials with mathematical regularity and with powerful apparatus for determining their reliability. In countries like this, where we can find more than twenty guaranteed brands of quick-setting Portland cement of different degrees, and where clay can be used for those constructions with advantage, and where we have regularity of manufacture, and finally in a country where we have powerful apparatus, coefficients can be obtained, as we have been doing for the past five years.

From these special advantages it seems that these works have culminated in the United States, taking a natural stand in New York and Boston, with specimens that have no rivals in any part of the world for lightness and resistance.

Cohesive construction differs from "mechanical construction" or the gravity system in that the latter is founded in the resistance of any solid to the action of gravity when opposed to the solid. From these conjunctive forces, more or less opposed to one another, the result is the equilibrium of the total mass, without taking into consideration the cohesive power of the material set between the solids, while the former has for a base the property of cohesion and assimilation of several materials, which by a transformation more or less rapid resembles Nature's work in making conglomerates.

The materials employed in the construction by gravity only require the physical quality of hardness; for the "cohesive construction" the materials must not only have proper physical conditions, but it is absolutely necessary to take into consideration the chemical properties of the substances employed.

Mr. Guastavino then had two arches of about 4½ feet span constructed before the audience in the same way they are being made in the new Public Library on Copley Square. The centers are ordinary boards cut to the proper curve, on which is laid a course of bricks or

tary science to put in practice the principles and maxims which have accumulated in great numbers in the text-books.

The Kriegsspiel invented by Herr von Reisswitz, and elaborated by his son, an officer of the Prussian artillery, has met with favor among the Germans since the early part of the present century; and now that this indefatigable people has applied to the art of war the same exhaustive and systematic study that has proved so efficient in other branches of scientific inquiry, many of the results of its labors have become embodied in this game.

Outside of Germany for a long time the game was regarded with little favor. After the war of 1866, however, it was cultivated extensively in Austria, and the war of 1870 opened the eyes of all Europe to its importance. In the United States it has been practiced to a limited extent since 1867, and its popularity has increased with the reputation of the Germans as a military nation. It is now practiced extensively in Russia, Italy, France, Belguim, and elsewhere.

The Kriegsspiel is played upon a topographical plan, with small blocks representing the troops, which are proportioned to the scale of the map, occupying as much space upon it as the troops would occupy in the field. These blocks are moved simultaneously, under the direction of an umpire, and at rates proportioned to the mobility of the different arms which they represent.

When the position of the blocks indicates that the hostile troops are within sight and range of each other, they are supposed to open fire, if the players desire it, and in this case it becomes the umpire's duty to decide the result upon the basis of experience. The rules of the game explain to him how to estimate the loss from this fire; for example, it may have been found that, in similar cases, the number of killed and wounded has varied from ten to twenty; by throwing a common die he decides whether to assign a greater or a less result to the case in view. The rules of the game also explain to him under what circumstances troops have been dispersed by the result of fire, and what would be the probable result of a hand-to-hand fight. Since the time of Von Reisswitz the game has been much modified; and the different forms which it has assumed may be classed in three groups.

The first form lays down a few arbitrary rules based upon general results, and leaves the die to decide in each case when the

dred in the way of instruction. Who would not feel more respect for this spirit than for that of more conservative leaders who have led thousands upon thousands of brave men to be mowed down like sheep because they have vainly assumed that the methods learned by experience and hard practice would suffice to meet the requirments of modern warfare, without taking into consideration the important changes in the armament?

But humanity revolts against these realistic experiments and has suggested methods that approximate as nearly to hostility as is consistent with a proper regard for human life and a measurable economy of resources; and it is by no means to be assumed that these methods are less instructive than the former. If the manœuvres are properly combined with other exercises and investigations, a system of instruction results which is even more useful than that afforded by unnecessary bloodshed, for it fixes the attention firmly upon each point in succession just as a skillful general throws all the strength of his armies upon the several fractions of his enemy and overcomes them in detail, and just as every conscientious and earnest man in other trades and professions devotes all his energies successively to mastering the difficulties of his calling.

To determine how far practice in the Art of War can be taught in time of peace, and without violating what is called in the text-books the "Peace Conditions," let us consider the form of manœuvres that differs the least from hostile encounters.

In general terms, in the autumn manœuvres in Germany a condition of hostility is assumed, the forces available are divided between the opposite sides in accordance with the problem, and the exercise proceeds as if in earnest, with slight modifications to avoid unnecessary destruction of property, until the combatants come within reach of each other's weapons. The umpires then decide the effects and consequences of the firing each in his own sphere, in accordance with recognized rules and principles, based upon the experience of past warfare which has been systematized and digested for the purpose. The defeated troops then fall back as directed by the umpires, and the operations proceed until the problem has been solved, or until the time fixed for the manœuvres has expired.

The following are some of the features in which this exercise differs from war: —

The highest order of manœuvers cannot be considered independently of Kriegsspiel, nor can the latter attain its highest usefulness unless supplemented by manœuvers; nor can either be developed without a proper study of military history and science.

MEETING 395.

The History and Theory of Cohesive Construction as Applied Especially to the Timbrel Vault.

BY MR. RAPHAEL GUASTAVINO.

The 395th meeting of the SOCIETY OF ARTS was held at the Institute on Tuesday, November 26th, at 8 P.M., Prof. G. Lanza in the chair.

After the reading of the records of the previous meeting, the chairman presented Mr. Raphael Guastavino, of New York, who continued the reading of the paper on "The History and Theory of Cohesive Construction as Applied Especially to the Timbrel Vault," which was begun at a regular meeting of the Society held October 24th.

Mr. GUASTAVINO said: We will begin by investigating the way in which this kind of arch works.

A "timbrel vault" of a single thickness of brick or tile has no more resistance than an arch or vault built by the "gravity system," because, no matter how good the mortar may be, there are only vertical joints, and the bricks or tiles are working as voussoirs, consequently this form of arch belongs to the gravity system, but if we put another course over the first breaking joints, and laid with hydraulic material, we will have the action of the cohesive force in this way, the mortar laid over the first course, or extrados, takes bond with it and also with the course laid on top. As soon as the cement sets, we will have shearing resistance represented by 17,820 lbs. per square

the centers are removed, and before the architect knows it, *he brings down the center of gravity still further* by hammering in little iron wedges or nails in the joints, covering them with mortar so as not to be seen. This is not good practice, for it destroys what cohesion may still be left in the joints, but has the advantage that it prepares the brick for second-hand material, freeing it from the mortar. In our arch in the same 6 feet we have only 13 joints, $\frac{1}{4}$ of an inch each, which is only $3\frac{1}{4}$ inches of mortar; consequently, as we know that the arch with no joints is the best, the one with the least is to be preferred.

There are other advantages equally important. We know that in every arch the curve of pressure changes with the position of the load; this means that every arch must be prepared for work by deflection or tension. Suppose an arch laid in bricks in such a manner as to receive a test for tension, the resistance of this tension depends upon the cohesion of the joints, or the resistance to tension of the mortar. But we said that this cohesion in the brick arches is very unsatisfactory, and is only a cushion in many cases, but when these joints have a good settlement the tension will only equal the cohesive strength of the mortar between the bricks, and with good Portland cement mortar ten days laid this strength is only from 80 to 150 pounds per square inch, when we have for our timbrel arch tensile strength (test No. 4875 and No. 4876) 287 pounds for 10 days, and 159 pounds per square inch for 7 days.

This shows that we have three advantages over the brick arches.

1st. The protection of the vertical joints by introducing the new strength coming from the horizontal breaking joints. These horizontal joints are in the 6′ arch, $1' \times 3$ horizontal joints or $144'' \times 6 \times 3 = 2592''$: in the brick arches 27 joints $\times 4 \times 12 = 1296$ square inches, but the tiles have not only the horizontal, but the vertical, equaling 638; $638 + 2592 = 3230$ for the tile arches, against 1296 for the brick arches. As the cement is the principal element of strength in the construction, if we call it 100 pounds for 10 days' setting, we will have for the brick arches 129,600 pounds, and for the tile arches 323,000 pounds.

2nd. The less number of vertical joints, amounting to only 5 per cent of the full span, while the brick arch has 10 per cent.

3rd. The resistance to the deflection (bending moment).

mortar composed of two parts lime, two parts sand, and three parts brick dust, in order to give very slow mortar, because cement requires repose for a certain length of time in which to set, and this putting it on in 6″ courses, and hammering it down, so jarred the whole mass that its rest was disturbed and its setting qualities killed. This can be seen in the use of our tiles; two minutes after the tile is bedded in the arch the cement has begun to set, and cannot be disturbed or used again, when the same cement in the mortar bed will remain several hours without setting.

In May, 1887, I commenced a serious of experiments in the department of Tests and Experiments with the Engineer, A. V. Abbott, and I obtained the following coefficients: —

COMPRESSION TEST.

No. 4817, May 3, 5 days, . . .	2277 lbs. per square inch.
" 4818, " 3, 5 " . . .	1624 " " " "
" 4869, June 6, 5 " . . .	1430 " " " "
" 4870, " 6, 5 " . . .	2911 " " " "
An average of 2060 lbs. per square inch.	
No. 7473, Oct. 21, 1889, 1 year, . .	3290 lbs. per square inch.

TRANSVERSE.

No. 4871, June 6, ...	90 lbs. per square inch.

TENSION.

No. 4875, June 7, ...	287 lbs. per square inch.

SHEARING STRESS.

No. 4873, June 6, in Portland Cement,	124 lbs. per square inch.
" 4872, " 6, in Plaster of Paris,	84 " " " "

The formula I am using is $TC = \frac{LS}{4r}$ for concentrated load, and $TC = \frac{LS}{8r}$ for distributed load, where T = thickness of arch in middle, or area of cross section. C = Coefficient = 2060 lbs. per square inch breaking load. S = Span. r = Rise of arch.

We use the first formula to get the thickness necessary at the center of the arch with a single load and independent of the weight of the arch itself. After that we find the line of the extrados of the arch in a graphical manner, derived from the formula given by Dejardin, for tracing the equilibrium profile of the extrados for the vaults, giving the section of the arch in the skewbacks or base of the arch on each side.

Fig. 5.

army. It is shown attached under the stock. Like the Metcalfe, it is a wooden block, perforated to hold the cartridges, but it has to be filled by the soldier.

Now we come to a very important development in magazines. These differ from the others I have described in this way, that the cartridges lie side by side, instead of being placed end to end, as in the tubular magazines.

The Lee gun is an example of this. An opening is made in the bottom of the receiver down through the stock, and the magazine is inserted from below. When one magazine is exhausted, it is taken out, and another one is put in its place. Several of these magazines are carried by the soldier, and belts are made to hold the prepared magazines. The magazines are made of steel. They have to be strong enough not to get dented or knocked out of shape, and each one has to be provided with a spring.

Figs. 6 to 8 illustrate this system. Fig. 6 gives a longitudinal section, showing the magazine in place; Fig. 7 a cross section, with the magazine removed. Fig. 8 gives a side view of the most recent form of Lee magazine.

Fig. 6.

(7) The magazine should show at all times just how many cartridges remain in it for use.

(8) In an assault, even after the magazine has been emptied by a rapid preliminary fire, it should be possible to refill the magazine during the rush if necessary, so that on reaching close quarters with the enemy the soldier may be able to deliver a rapid and abundant fire after the bayonet charge.

(9) The arrangement of cartridges should be such that the bullets of the cartridges cannot be upset and injured in the magazine.

(10) There should be no danger of the explosion of cartridges in the magazine.

(11) It should allow the main parts to be dismounted, cleaned, and put together again, even in the field or under fire if necessary.*

(12) The gun should be strong and simple, even if rude in construction, to stand the wear and tear of drill and service.

(13) It should not require removal from the shoulder in continuous firing.

The *Revue Militarie de l'Etranger* adds: —

(14) In continuous firing, the gun should not require removal from the shoulder, nor removal of finger from the trigger.

(15) Filling the magazine should not require opening the breech, nor withdrawing the charge if the piece is loaded.

(16) It should be as easy to refill the magazine as to put a single cartridge into the simple breech loader, cartridges being carried in light boxes to serve as chargers.

The 4th, 5th, 15th, and 16th requirements indicate that the magazine should allow refilling by inserting the cartridges one at a time, when partly exhausted, or all at once when the magazine is empty.

Other authorities say the magazine should be detachable, easily replaced when empty by another full magazine held in reserve, but all agree that the perfect magazine should allow a fresh supply of cartridges to be rapidly added to the gun for instant use. The great principle sought for, first in breech-loaders, now in magazine guns, has been " to reduce to a minimum the time during which the soldier remains with gun unloaded after each shot. It is not always necessary for a man to fire rapidly, but he should be able to load rapidly, as this gives him more confidence and affords a longer time for aiming with care.

* This seems to be a very unnecessary demand.

In the Austrian gun, the Mannlicher, the bolt, instead of being pushed in and turned, is operated by a forward-and-back motion simply. The magazine is fixed under the receiver, like the Rubin. A packing case filled with cartridges is inserted in the magazine and left there, the cartridges being fired from the case, and when the case is emptied it drops through a slot in the bottom of the magazine. This gun cannot be used for single firing, and the cartridges cannot be inserted one at a time. It also has the disadvantage that it is necessary to open the breech to fill the magazine, as the packing case has to be inserted through the receiver.

Fig. 16 shows the Mannlicher gun, and Fig. 17 the packing case used to fill it. Fig. 18 shows the small caliber cartridge with projecting flange used in the Mannlicher. The flanges have to be overlapped in the magazine to leave the top one free to move forward with the bolt, and a corresponding arrangement is necessary in the packing case, giving it a definite top and bottom.

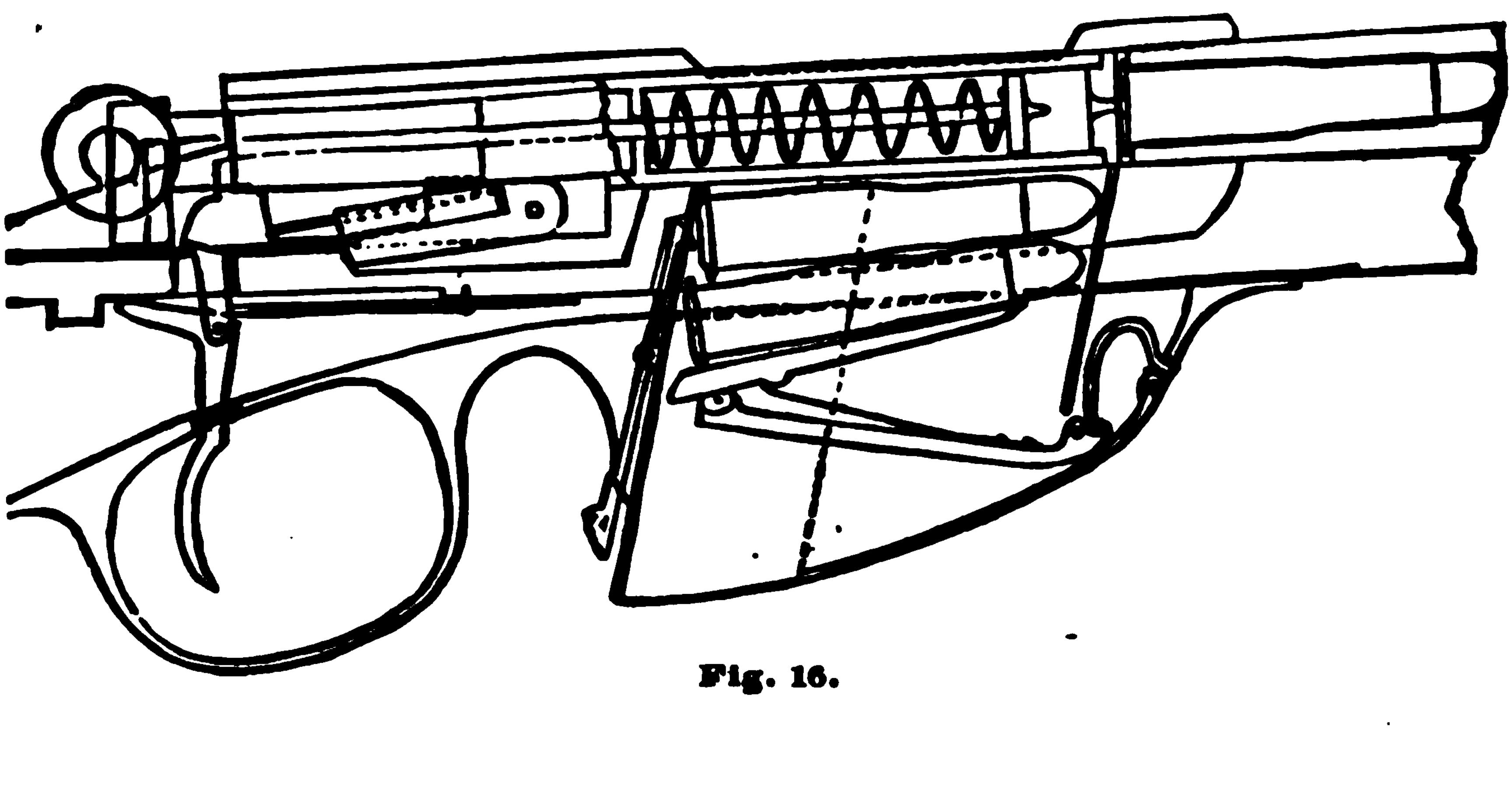


Fig. 16.

Fig. 20.

Most of the guns already spoken of were exhibited, as were also the Peabody, the Colt rifle, and several others.

Numerous drawings, representing sections, etc., of many styles of guns, arranged in the order of development, were used to illustrate the lecture. Among them were drawings of the Maxim automatic recoil rifle, and an electric gun. Illustrations were given of magazine guns, like the Spencer shot gun, and the Colt rifle, operated by means of a slide under the barrel; also of the Burgess gun, operated by means of a slide on the small of the stock. The latter has the advantage of operation with the right hand, while the left hand, grasping the barrel, steadies the piece.

At the close of the paper, Capt. Russell expressed his thanks for the courtesy shown by Hartley & Graham, of New York, William Read & Son, and J. P. Lovell Arms Co., of Boston, in offering and furnishing arms for exhibition.

MEETING 397.

The Physical Properties of Iron and Steel at Higher Temperatures.

BY MR. JAMES E. HOWARD.

The 397th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, January 9, 1890, at 8 P. M., Prof. Gaetano Lanza in the chair.

After the reading of the records of the previous meeting, the Chairman introduced Mr. James E. Howard, of Watertown Arsenal,

Table II. SECOND SERIES OF STEEL BARS.

From these tables it appears that the expansion of wrought iron and mild steel is greater than that of hard steel and cast iron. The expansion of mild steel was found to be about 67 ten millionths of its length per degree Fahr. In steel of 1 per cent carbon the rate of expansion falls to 61 ten millionths, and the expansion of the cast iron was less than that of the hard steel.

In the first series of experiments variations in the rate of expansion followed approximately the carbon of the steels, and also the quantity of iron present.

In the second series there was a wider range taken by the other elements, and indications here led to the conclusion that carbon has the greater influence upon the rate of expansion. This deduction applies to annealed metal, or that which has been finished hot.

Ten bars of the first series, representing steels containing from .09 to .97 per cent carbon, were subjected to the special treatment of being heated a bright cherry red and quenched in oil, reheated and quenched in water. The first quenching was done in oil at 80 degrees Fahr.

The moduli of elasticity were obtained with the first series of bars at atmospheric temperatures, and again at higher temperatures up to 495 degrees Fahr. The specimens were strained in a bath of hot oil. Micrometer observations were taken in a similar manner to those when determining the coefficients of expansion, that is, the conical points of the measuring instrument reached down through the surface of the oil in the bath to the drilled holes in the specimen, and enabled the strains to be measured. Elevation of temperature is found to lower the modulus of elasticity. The different grades of steel, wrought iron, and cast iron behaved alike in this respect, although differing in degree.

The reduction in the modulus of elasticity for a range of about 400 degrees, beginning with atmospheric temperature, was found from 3,595 to 8,294 lbs. per square inch per degree Fahr. for the steels. Lower values were obtained with the cast iron and intermediate values with the wrought iron.

It does not appear, however, that the reduction takes place at a uniform rate with increase of temperature; or, stated differently, the reduction is not directly proportional to the expansion of the metal by heat.

Two bars of the second series were experimented with at temperatures reaching 1,400 degrees Fahr. The heating was done in a hot-air muffle, estimating the temperatures of the tests from the expansion of the metal between reference points 10 inches apart. A specimen which contained .26 per cent carbon had an apparent modulus of elasticity of 29.000,000 lbs. per square inch at 70 degrees Fahr., which was lowered to 16,981,000 at 1,353 degrees. And another specimen containing 1.07 per cent carbon showed a reduction from 29,771,000 at 70 degrees, to 14,173,000 lbs. per square inch at 1,400 degrees Fahr.

Observations on these two bars at intermediate temperatures indicated an accelerating rate of reduction of the modulus of elasticity as the temperature increases. Overstraining at atmospheric temperature causes a temporary reduction in the modulus of elasticity. The effect of overstraining at high temperatures upon this point is not conclusively indicated by these experiments, the evidence of different tests being of a conflicting nature. This important feature will be investigated in subsequent tests.

reach the place of first minimum strength somewhat earlier than the hard steels. The hard steels from this first minimum increase in strength rapidly until the highest strength is attained, after which a rapid decline follows. The mild steels retain a high strength over a wider range of temperature, and do not lose in strength so rapidly as the harder metal. The greatest loss observed in passing from 70 degrees to the place of first minimum strength was 6.5 per cent at 295 degrees, which was shown by a bar containing .89 per cent carbon. The greatest gain in per cent over the strength at 70 degrees was 25.8 per cent, shown by steel of .09 per cent carbon, although in pounds per square inch it was exceeded by steel of .57 per cent carbon where the gain was 15,120 lbs. per square inch, or 12.8 per cent. The total difference in the strength of steel containing .57 per cent carbon between 214 and 587 degrees maximum and minimum places respectively was 21,200 lbs. per square inch. As higher temperatures are reached the several grades of steel approach each other in strength. Thus steels which differ in tensile strength over 100,000 lbs. per square inch at atmospheric temperature differ at the temperature of 1,600 degrees less than 10,000 lbs. per square inch. Their relative positions are retained throughout, that is, steels which are strongest cold are also strongest hot, at least up to the highest temperatures reached by these experiments.

Referring to the relative influence of higher temperatures upon the elastic limit and tensile strength, steel of .09 per cent carbon at the temperature of 460 degrees reached the maximum observed tensile strength for this grade of metal, and displayed a strength of 125.8 per cent that at 70 degrees, but at this time the elastic limit was 78.2 per cent that of the cold bar, and at 847 degrees the tensile strength was 8.4 per cent above the cold metal, while the elastic limit was only 51.5 per cent that of the cold bar. The other grades of steel behaved in a similar manner with less pronounced differences in the harder metal. One grade of wrought iron, designated by the letter B, resembled the mild steel in its behavior. Another wrought iron, called iron A, furnished an exception to the rule, that the elastic limit steadily diminishes with increase of temperature. At 689 degrees this iron had an apparent elastic limit 102.2 per cent of that found at 70 degrees. Iron A had been strained with 42,320 lbs. per square inch seven years before these hot tests were made, and this particular

certain stresses at intermediate temperatures than at either higher or lower temperatures. An illustration of this kind is furnished by a bar of .31 per cent carbon tested at 569 degrees, which displayed less elongation under stresses above 50,000 lbs. per square inch, than other bars of the same grade of metal tested at higher or lower temperatures.

The stress on the ruptured section resembles somewhat but not closely the curve of tensile strength. The speed of testing affects this value more or less, and failure in detail may render it difficult to distinguish when local contraction ceases and rupture begins. With hard and brittle metal the stress on the ruptured section does not differ largely from the tensile strength: the converse is true of ductile metal. Steel of .09 per cent carbon tested at 492 degrees reached 118,100 lbs. per square inch stress on the contracted section at the time of rupture. The tensile strength referred to the primitive area was 64,560 lbs. per square inch. The contraction of area at the place of rupture also varies with the temperature of the metal. It appears that contraction of mild and medium hard steel is somewhat less at 400 to 600 degrees than at atmospheric temperature, and within this range of temperature there is a tendency to fracture in an oblique direction across the bar. This characteristic is significant in so far as it harmonizes with the brittleness observed in bending tests at these temperatures. The hard steels showed substantially the same contraction up to 500 degrees. Above 500 or 600 degrees the contraction increased with the temperature, with the exception of the hardest grades, which showed a stage of diminished contraction at 1,100 to 1,200 degrees, until at the highest temperatures some of the bars were drawn down almost to points. A specimen of .37 per cent carbon, fractured at 1,572 degrees, contracted 98.9 per cent. Occasionally there are indications specially noticeable when large contraction occurs that rupture in some specimens begins at the center of the bar. A test was discontinued after reaching 94.4 per cent contraction of area, the temperature at the time was 1,451 degrees. By filing away a portion of the outside metal after cooling, a cavity at the center of the bar was disclosed. Center-punch marks on the surface of the specimen near the place of rupture have elongated upwards of 300 per cent.

The rate of speed of testing may, within limits, modify the results with ductile metal at atmospheric temperature, and has a decided

limit and tensile strength, and generally a noticeable increase in the contraction of area. But simply heating without straining was found to anneal and lower the strength of bars of .97 per cent carbon exposed to temperatures of 1,529 and 1,684 degrees respectively, the contraction of area, however, remaining unchanged.

The data thus far developed seem insufficient to explain the relative influence on the final strength of the metal due to exposure to high temperatures, the duration of such exposure, and the tensile stress then applied.

It does not seem inconsistent with observed facts to believe that each of these features may arrive at a stage of relative greatest importance at different places along the thermometric scale.

The color of the bars after cooling was not sensibly changed by temperatures below 200 degrees. After 300 degrees the metal was light straw colored; after 400 degrees, deep straw; from 500 to 600 degrees, purple, bronze colored, or blue; after 700 degrees, dark blue and blue-black. After 800 degrees the final color affords less satisfactory means of approximately judging of the temperature, the color remaining a blue-black and darker, until a thick magnetic oxide is formed. A smooth glazed surface was found on specimens heated to 1,000 to 1,200 degrees, which offered considerable resistance to the effect of acids, and against corrosion in a damp atmosphere. The oxide tints found at lower temperatures were immediately removed by the action of acids. At about 1,100 degrees the surface oxide reaches a tangible thickness, a heavy scale of .001 of an inch to .002 of an inch forming as higher temperatures are reached. The red oxide appears at about 1,500 degrees Fahr. When the oxide has a tangible thickness, it is more or less loosened from the surface of a ductile metal ruptured cold. Some specimens ruptured after exposure to the lower temperatures of 600 to 700 degrees have had the surface coloring slightly broken, but such is not generally the case. The fractures of specimens with straw-colored cylindrical surfaces were not colored. Those with blue surfaces showed fractured ends deep straw and brown. The fractures of dark blue and blue-black specimens agreed with the cylindrical surfaces. The specimens were allowed to cool immediately after rupture, hence the surfaces of the fractured ends were exposed to the atmosphere only a brief period of time, while at the maximum temperature.

at temperatures from 70 to 700 degrees, over which range the results of the tensile tests of the plain bars were corroborated. Riveted joints at 200 degrees showed less strength than when cold; at 250 degrees and higher temperatures the strength exceeded the cold tests, and when overstrained, approaching the limit of rupture, at 400 to 500 degrees there was found when completing the test cold an increase of strength over the duplicate cold test made in the ordinary manner. A single riveted butt joint tested at 500 degrees ruptured with 81,050 lbs. per square inch on the net section of plate, whereas the corresponding joint tested cold failed in the same manner with 65,000 lbs. per square inch. Another joint at 500 degrees reached 119,980 lbs. per square inch compression on the bearing surface of the rivets. Still another joint, which was strained at 500 degrees, then cooled to 150 degrees and ruptured, sustained 137,110 lbs. per square inch compression on the bearing surface of the rivets.

As none of these joints failed by direct crushing of the metal at the bearing surfaces, without defining the crushing limits under these conditions of test, we are enabled to say the metal is capable of sustaining very high compressive stresses in this zone of temperature.

Rivets which sheared cold at 40,000 to 41,000 lbs. per square inch at 300 degrees sheared at 46,000 lbs. per square inch; and at 600 degrees, the highest temperature at which joints were ruptured failing in this manner, the shearing strength was 42,130 lbs. per square inch.

The internal strains in some oil-tempered and annealed steel cylinders have been investigated. The cylinders were numbered 7, 8, and 21.

The salient features of the investigation were that cylinder No. 7, which was oil-tempered, annealed, and then retempered, was found to have the entire surface metal, exterior bore, and ends in an initial state of compression, and the interior of the mass in a state of tension. The maximum stresses found were 47,161 lbs. per square inch compression, and 938 lbs. per square inch tension. The latter stress not representing, however, the maximum amount which was in the cylinder when entire, the inaccessibility of the tensile metal at the time preventing that value being ascertained. The strains in cylinders Nos. 8 and 21 were of small magnitude, showing the final process of annealing to have been very efficient. The middle section of cylinder

the internal strains, the restoration in chord measurement which followed the removal of the wedge after this temperature showed the metal had an appreciable elastic limit at that temperature, although a low one. This same ring was next heated cherry-red and quenched in oil. Now, subjecting it to the temperature 410 degrees, wedged apart substantially the same amount as before, and the permanent set found was over six times the magnitude of the set after heating to nearly the same temperature in the first instance. This remarkable difference in the persistence of internal strains displayed by the ring before and after the last retempering demands further investigation in order to ascertain the influence of intervening periods of time, of different initial states of hardness, and different methods of tempering and hardening.

Specific gravity determinations with sectors from cylinder No. 7 (the pieces were small, weighing in air about 33 grammes each) showed, after heating cherry-red and quenching in oil, a slight increase in density, and when quenched in water from the same temperature a decided loss in density. Again heating cherry-red, and reversing the pieces in the quenching fluids, the same differences were displayed as before, that is, quenching in oil caused an increase in density, quenching in water a decrease in density. Heating nearly white hot and quenching in oil caused a decrease in density, as the water had done at lower temperature. As similar treatment is found to cause in different specimens both internal strains and changes in density, these two features may be regarded as correlated functions.

From what has just been said we see that internal strains are released by elevation of temperature, and the extent to which they are released depends upon the temperature reached. Earlier remarks stated that the elastic limit diminishes with increase of temperature, therefore we infer that strains in excess of the elastic limit at the annealing temperature are released by that temperature, and complete elimination of internal strains would therefore require a temperature at which there was practically no elastic limit.

Phenomena attending the over-straining and alternate straining of iron and steel are under investigation. It appears that certain steel bars which originally possess an equality of elastic limits under tensile and compressive stresses, when loaded beyond the elastic limit in either direction, lose in the elastic limit in the opposite direction.

At the beginning of the present century the galvanic cell was discovered. This invention was of but very little commercial importance until the discovery of the Morse telegraph in 1837. The discovery of the carbon transmitter of telephony still further increased its value, and today there is no branch of electrical engineering of more importance than that of the galvanic or voltaic battery; yet, strange to say, there has been no commercial instrument in the market for measuring the electro-motive force and internal resistance of batteries up to the present time. The result has been that there is a vast amount of superstition afloat in regard to batteries, and, outside of a few electrical laboratories, absolutely nothing is known in regard to them.

In the fall of 1887 I began a series of tests upon various batteries, with laboratory apparatus, which led to the invention of the apparatus under discussion this evening. The electrical arrangement for determining the electro-motive force of batteries was the well-known Lacoine's method, which is as follows: —

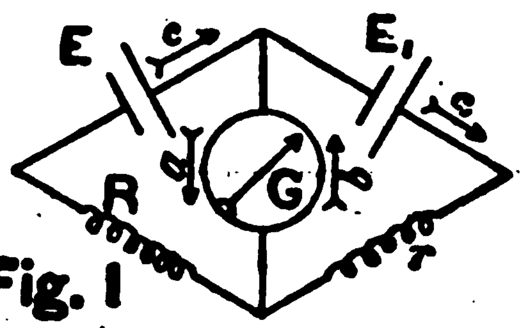


Fig. 1

In Fig. 1, E is a standard battery whose electro-motive force is already known. E_1 is the battery whose electro-motive force we wish to find. Let these letters also represent the electro-motive forces of these batteries, respectively. R represents a fixed resistance; r, a resistance which we can vary at will. G is a galvanometer. The battery E tends to send a current through the galvanometer in the direction indicated by the arrow A, tending to cause a deflection of the galvanometer needle, say to the right. The battery E_1 tends to send a current in the opposite direction, indicated by the arrow B, tending to cause a deflection of the galvanometer needle to the left. When both batteries are acting upon the galvanometer, its needle will be deflected to the right or to the left, according to which of these tendencies is the stronger. It is evident that the current that the compared battery E tends to send through the galvanometer can

ances, all the other plugs between A and B being inserted. Resistance is then introduced in the variable side of the bridge, so that upon closing the key K no click is heard in the receiver when the telephone circuit is closed between D and F. The theoretical arrangement is shown in Fig. 3.

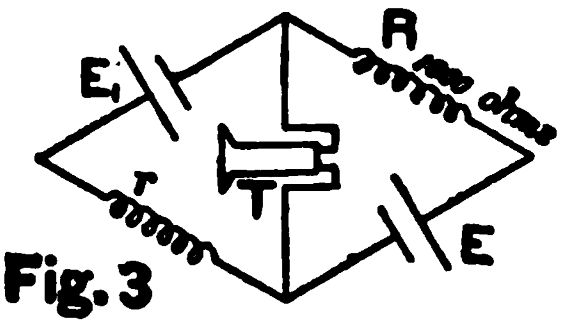


Fig. 3

This is obviously a similar arrangement to that described before, for R, the fixed resistance, controls the current delivered by the standard battery, and the variable resistance r controls the current given by the compared battery.

The apparatus that we then used for determining resistances of batteries was constructed upon the well-known Mance's method, but since it has no special bearing upon the apparatus which I shall describe tonight for this purpose, we will give it no further consideration.

Let us now discuss more in detail Lacoine's method of determining electro-motive force. From Figs. 4, 5, 6, and 7 it will be seen that there are four ways in which the galvanometer resistances and batteries can be grouped.

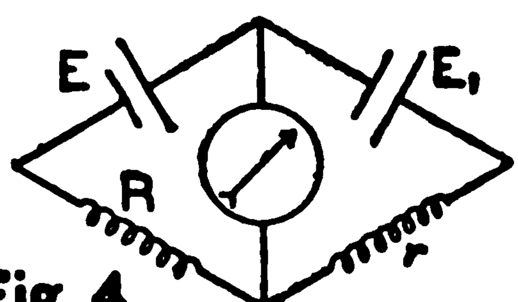


Fig. 4

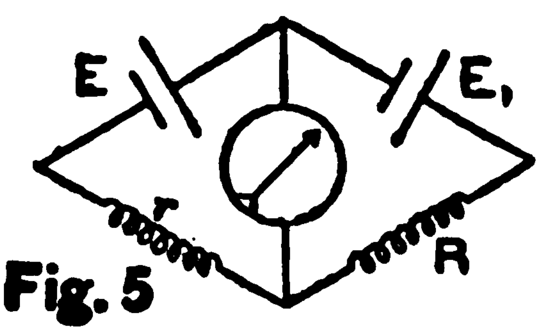


Fig. 5

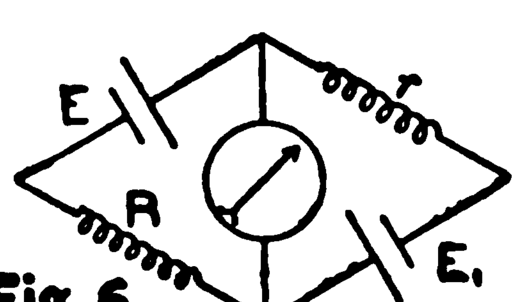


Fig. 6

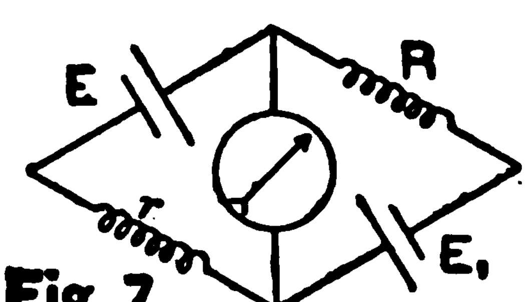


Fig. 7

$$E_1 = ER\frac{1}{r} = 1.10 \times 1000\,\frac{1}{200} = 5.5 \text{ volts.}$$

Referring to Figs. 6 and 7 it will be seen that the electrical connections in Fig. 6 are similar to those in Fig. 4, the functions of R and r being the same in both cases, and the formula representing the value of E_1 is the same as in Fig. 4.

$$E_1 = \frac{E}{R}r$$

Also, the resistances in Fig. 7 fill the same office as in Fig. 5, and we have for the value of E_1, as in Fig. 5,

$$E_1 = ER\frac{1}{r}$$

Let us now discuss these two different applications of Lacoine's method of measuring electro-motive force, to determine their relative defects and advantages. Let us assume that we are limited to an ordinary Wheatstone's bridge, with coils ranging from 5,000 ohms to 1 ohm, the sum total being 10,000 ohms. For very accurate work I have considered it advisable to use as high a value for the fixed resistance as 10,000 ohms, and we will also assume that our standard is a Daniell's cell of 1.1 volts, and that we are measuring a storage battery of 2.2 volts. Then, if we have the arrangement shown in Fig. 4,

$$E_1 = \frac{E}{R}r$$

Or, $2.2 = \frac{1.10}{10{,}000}r$, whence $r = 20{,}000$ ohms.

But our Wheatstone's bridge only gives us 10,000 ohms, and we should be unable to measure so high an electro-motive force with the coils at our disposal.

With connections given as in Fig. 5, we should have with the same data: —

$$E_1 = ER\frac{1}{r}$$

Or, $2.2 = 1.10 \times 10{,}000 \times \frac{1}{r}$, whence $r = 5{,}000$ ohms.

And since E_1 varies directly as r, we can construct our coils thus:

1.00	volt	corresponds	to	1,000	ohms	in the	variable	resistance.
.50	"	"	"	500	"	"	"	"
.20	"	"	"	200	"	"	"	"
.20	"	"	"	200	"	"	"	"
.10	"	"	"	100	"	"	"	"
1.05	"	"	"	50	"	"	"	"
.02	"	"	"	20	"	"	"	"
.02	"	"	"	20	"	"	"	"
.01	"	"	"	10	"	"	"	"

Consequently, if we construct a voltmeter with variable resistance coils of these values, we shall have a direct-reading instrument reading from 0.01 to 1.00 volt. To make this method direct-reading it is not necessary to make the value $\frac{E}{R}$ some ratio of unity, although this is the simpler way. For instance, suppose we compute the value of r which would make E_1 unity, the standard battery and fixed resistance having been chosen beforehand. Let us assume our fixed resistance R is 1,375 ohms, and our standard battery 1.1 volts; then we have for the value of r for one volt:

$$1 = \frac{1.1}{1,375}r, \text{ from which } r = 1,250.$$

Then we could build a direct-reading voltmeter by making the variable resistance coils as follows:

For	1.00	volt,	1,250	ohms.
"	.50	"	625	"
"	.20	"	250	"
"	.20	"	250	"
"	.10	"	125	"
"	.05	"	62.5	"
"	.02	"	25	"
"	.02	"	25	"
"	.01	"	12.5	"

In a direct-reading voltmeter constructed upon this principle the electrical connections and resistances would be as shown in Figs. 8, 9, and 10.

volts. The terminals of the source of electro-motive force to be measured are connected, the positive to terminal A, and the negative to terminal B. The main circuit is opened at some point, C, and the terminals connected to the upper contacts of a double contact key. The galvanometer circuit is opened and the terminals taken to the lower contacts of the key. In this manner the standard battery circuit is kept open until the key is depressed.

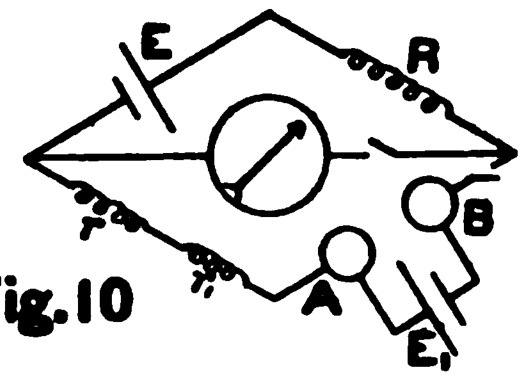


Fig. 10

Let us see if a direct-reading voltmeter can be constructed upon the principle of the special case where $E_1 = E\,R\frac{1}{r}$. We will give to the fixed resistance R, as before, such a value that the product ER shall be unity or some decimal of unity, for instance, 1,000. Then for

1.00	volt,	$r =$	1,000	ohms.
.50	"	"	2,000	"
.20	"	"	5,000	"
.20	"	"	5,000	"
.10	"	"	10,000	"
.05	"	"	20,000	"
.02	"	"	50,000	"
.02	"	"	50,000	"
.01	"	"	100,000	"

But a voltmeter built in this manner, of coils ranging from 1,000 ohms to 100,000 ohms for the fixed resistance, would not be direct-reading. For instance, suppose the battery to be measured had an electro-motive force of .7 volt, the resistance would be intermediate between 1,000 and 2,000 ohms, but we have no such coils or combination of coils that would give the desired resistance.

One way to obtain a direct-reading voltmeter with this arrangement is to make a slide resistance out of our variable coils, requiring for a range from 1 volt down to .01 volt 100 distinct coils and over 100,000 ohms resistance. We could in this manner make a direct-

S is the battery whose electro-motive force and resistance is to be measured. A and B are the terminals of the voltmeter, the remaining portions of the voltmeter not being shown. One terminal of the 10-ohm coil is connected to A, and the other goes to the adjacent brass strip a. A connection is carried from a to the upper contact of a triple contact key, and a lead taken back to the second strip b. With plug P removed it will be seen that when the triple contact key is depressed, the 10-ohm coil will be introduced between terminals A and B, and with plugs P and P_1 inserted the 10-ohm coil can be kept in circuit around the terminals of the battery for any desired time. With plug P_1 removed the 10-ohm coil is evidently inoperative. This arrangement accomplishes, then, the three ends desired, and we have combined in one instrument both a voltmeter and an instrument for determining the internal resistance of batteries.

AMMETER.— In many cases we do not care to know the electromotive forces of batteries, or their resistances, but a quantity dependent upon both of these factors. We wish to know the current of electricity which they will send through a given resistance. It is also of great value to know the current flowing through a given system, say a telephone transmitter, an incandescent or an arc lamp. The addition of one more coil to the instrument, as described, will convert it into a direct-reading ammeter, the figures before denoting volts now registering amperes.

Let us see how this is accomplished. From Ohm's law it follows that if we have a current of one ampere flowing through one ohm, it will generate a difference of electric pressure of one volt at the terminals of this resistance. Now, if between the terminal A and B of our voltmeter we connect a 1-ohm coil, and if we send a current of one ampere through it, the voltmeter will register one volt. Conversely, if our voltmeter registers one volt we know that a current of one ampere is flowing through the circuit of which the 1-ohm coil forms a part. This coil should be placed in our combination instrument above described, adjacent to the 10-ohm coil, added for battery resistance measurements, the connections being as shown in Fig. 12.

This is the same arrangement that would be used in the second measurement for battery resistances.

It is evident that we have in circuit between the terminals *B* and *C* 1,000 ohms when the key is depressed, and that there are 10 ohms of this resistance included between the terminals of the voltmeter proper. Consequently, $\frac{1}{100}$ part of the electro-motive force between the terminals *B* and *C* will be included between *A* and *B*. It follows that if we measure the electro-motive force between *A* and *B* by our voltmeter proper under these circumstances, and multiply this voltage by 100, we shall have the total electro-motive force between *B* and *C*. It is only necessary, then, for high voltages to use terminals *B* and *C*, and to move the decimal point of the voltmeter reading two places to the right.

RANGE OF THE APPARATUS.—We can with perfect safety measure up to 200 volts in this manner, by properly constructing our 990-ohm coil and the 10-ohm coils, but for higher voltages it is better to sacrifice somewhat on our battery resistance measurements, and make the connections thus (Fig. 14):

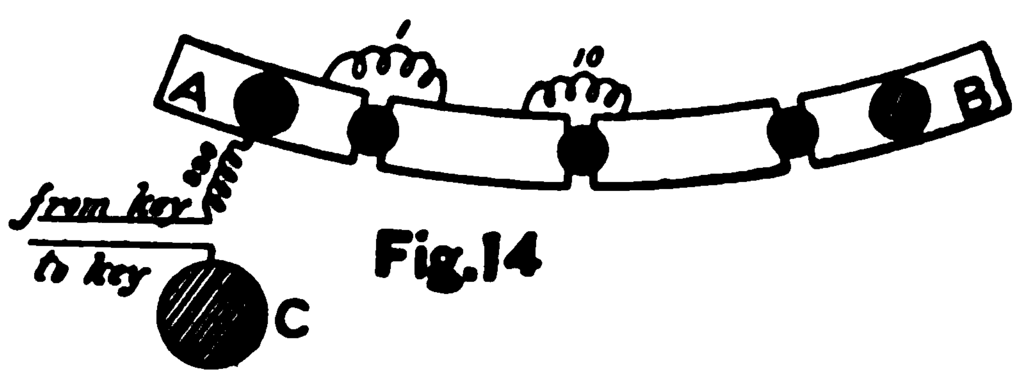


Fig. 14

In this manner any slight resistance which might be introduced by oxidation of the contacts from sparking at the key would be thrown into the 990-ohm coil rather than into the 10-ohm coil. The instrument could still be used for determining battery resistance, the 10-ohm coil being introduced manually.

The following data will indicate how the range of the instrument can be extended so as to cover any voltage used commercially, even those employed in arc lighting. It is evident that some of the values given cannot be realized in practice, but there is no difficulty in selecting a combination that will cover every case desired.

Used as an ammeter by the employment of a 1-ohm coil, we have seen that its range is from .01 to 6 amperes, and where the introduction of 10 ohms into the circuit is not objectionable, the 10-ohm coil used for battery tests can be employed in place of the 1-ohm coil, and the range would be in this case from .001 to .6 amperes. The following data give the range of the instrument with various coils:

10.0000	ohm-coil.	Range	.001	to	.6	amperes.
1.0000	"	"	.010	"	6.0	"
.1000	"	"	.100	"	60.0	"
.0100	"	"	1.000	"	600.0	"
.0010	"	"	10.000	"	6000.0	"
.0001	"	"	100.000	"	60000.0	"

These figures are somewhat delusive, however. For instance, take the .001 ohm-coil, 6,000 amperes would cause a waste of 36,000 watts, or 48 electrical horse-power, in our voltmeter alone. On the other hand, we could easily measure 1000 amperes with this coil properly constructed, the loss in this case being only a little over one horse-power. An intelligent use of the above coils will enable us to cover nearly every case in practice. For special work a more delicate galvanometer, enabling us to measure to .0001 volt, might be employed. It is evident, then, that the apparatus can be constructed so as to cover any range of current strength or electro-motive force desired.

In criticism of the instrument the objection might be raised that there is no battery of sufficient constancy to be employed with the apparatus. It will be observed, however, that it is not necessary to use a standard battery, but only one that shall remain constant for a considerable time. The best battery to employ would be some form of Daniells cell, were it sufficiently portable. I have used a modification of the Daniells cell for two years with a stationary battery testing apparatus of this type with perfect success. A comparison of the battery with the Latimer-Clark cell at various times has shown a variation of less than one per cent. For convenience, however, it is necessary to use some form of dry battery. I first used a chloride of silver battery of about 20 ohms internal resistance, but found its resistance to be too variable for the desired accuracy of one per cent.

on or near the banks called attention to the absolute necessity of removing or abating such nuisances. The removal consisted in the application to land or the discharge of the sewage into the sea or farther down the brook or river flowing through the town, perhaps near some other town. In many cases the nuisance was abated, never removed entirely, by the use of chemicals, and the precipitation of most of the suspended matter, and the destruction or oxydation of a little of the organic matter in solution. Suspended matter must either be deposited in settling tanks as sludge or in some river or harbor as mud until dredged out. The organic matter is the most difficult to destroy or remove, and is the part most dangerous to health. The oxydation of the organic matter can be accomplished by one method only, chemical action, whether that be produced by filtration, the addition of chemicals, or electrolytic action. A filter is sufficient when employed intermittently, for then the filtering material becomes aerated, *i. e.*, charged with atmospheric oxygen during the periods of rest, and this oxygen destroys the organic matter of the sewage. Oxydation can also be accomplished more or less expensively by chemicals. The electrical method differs from the above methods in two points; first, the oxygen and chlorine that produce the burning up or oxydation of the organic matter is made by decomposing, by the aid of a current of electricity, the water and chlorides of the sewage itself; second, the oxygen and chlorine act much more powerfully at the moment of their formation, being set free in what is called a "nascent" state.

Mr. Wm. Webster, F.C.S., engineer and contractor for the construction sewage works, including precipitation tanks, during a series of successful experiments in the purification of sewage by electrolysis, settled at last upon two metals suitable for electrodes, aluminum and iron, the latter, on account of its cheapness, practical on a commercial scale. He first tried large tanks in which the liquid was treated and allowed to settle.

Strips of sheet iron are placed in a jar of sewage and a current passed through the solution. Hydrogen is given off from the plate connected with the zinc pole of the battery, and from the positive pole, *i. e.*, the strip where the current enters, chlorine and oxygen are set free in a "nascent" state, probably combining with the iron to form a hypochlorite of iron which is immediately reduced to ferrous car-

bon a piece of iron be connected also, a hypochlorite of that metal is made and may be used for the same purpose as the chlorine alone. One-third grain of chlorine is found to disinfect one gallon London sewage. By automatic attachments such an apparatus is used in the household, and the liquid supplied and drawn off at intervals when needed for use. The ordinary Leclanché cells, five or six in number, will last several months and produce two gallons of chlorine solution daily.

Mr. Webster's experimental station is located at Crossness about 13 miles from London. The sewage is pumped into a shoot 18 inches square, 400 feet long, and filled with wrought iron plates in groups of 15, a large number of which connected in multiple or parallel form sections in series with each other. A space of two or three feet in the shoot between sections is sufficient to prevent undue leakage. The 70 h. p. Mather and Platt dynamo gives 20 volts. The six sections take approximately 3 volts per section, current 320 amperes. It would be economical as regards the loss in the conductors to have more sections in series, but the number is limited to 25 or 30 on account of danger to the workmen, it being impossible to avoid grounds, as both ends of the shoot have liquid connection to the earth at the inlet and outlet. The consumption of the iron plates is from 1 to 2 grains per gallon of sewage treated if cast iron is used. Wrought iron scales badly and is more expensive, but from its lightness is well adapted to experimental work. The velocity in the shoot is about 10 to 25 feet a minute, or from 4,000 to 10,000 gallons per hour. The color shows no apparent change for 20 to 30 feet, then numerous bubbles come to the surface, and farther on these have a brown color, and near the end the liquid is dark. At points in the shoot the current runs over or under an adjustable board, giving a thorough mixing and a complete control of the level in each section of the shoot. It is desirable that the outlet should be below the level of the liquid in the precipitating tank that it may settle rapidly and to a compact form. As the churning action in the shoot has liberated all of the hydrogen, the precipitate settles at once, and in two hours the clear effluent may be drawn off and discharged directly or through an electric filter into any convenient stream; or without settling it may be run on to land which does not become clogged, and the precipitate or sludge rapidly drying on the surface is easily worked into the land. The sludge as

The plant that Mr. Webster has built at Crossness to test his system is only relatively experimental, having a capacity of 500,000 gallons a day, and by extending or enlarging the shoots, 1,000,000 gallons, for which there is sufficient room and power. At 30 gallons per head per day this would be ample for a town of 30,000 inhabitants in England. In the United States the sewage is larger in quantity but more dilute, requiring larger shoots and more iron surface, *i. e.*, a somewhat greater first cost but about the same operating expenses. In England the cost of a 1,000,000 gallons a day works, with duplicate engines and dynamos and iron plates lasting ten years, is estimated at $30,000, or $1 per inhabitant, but would be materially less here, if the cost of steam and electrical machinery and contract construction work in the two countries furnishes any basis for comparison. The expense of 300 pounds of iron daily consumed has been estimated in the cost of the plant, and the labor of four men and the consumption of a ton of coal or less make a daily expense of $13. A visitor at the station is invariably impressed with the success of the system, no unpleasant odor is perceptible, and the appearance of the sewage during treatment and precipitation is far more inviting than the surface of the streets of the crowded parts of even Boston. The epicures of London may be looked upon as opposed to this system, for, according to Lawes, the fish of the Thames feed on the sewage; and where will the tempting and luscious whitebait, that is now taken only in the Thames estuary, and for which the cuisines of London are famous the world over, find its food and the dredgers find employment if the crude sewage is successfully treated by the electric current?

The paper was illustrated by numerous diagrams and lantern views.

For structural purposes crucible steel, hardened by an alloy of chromium, was employed in the Eads St. Louis bridge in 1869. Though successful in all respects, the experiment has not been repeated.

Practically, mild steel for bridge building dates from 1879, when Bessemer plates and girders were incorporated in the approaches to the East River bridge. From this date also open-hearth steels entered largely into bridge structures. None of the bridge steels of that time would now be called mild steel, as the T. S. was from 70,000 to 80,000 lbs. per square inch, and the elongation only 20 per cent in 8 inches. The total amount used was small, as the aggregate of all classes, crucible, open hearth, and Bessemer, was but 18,000 tons in the fifteen years from 1869 to 1884.

In ship building we did nothing whatever prior to 1879. In that year three vessels of an aggregate tonnage of 246 tons were built for river navigation. Up to 1883 five more, including lighters, were constructed. The total tonnage to this date was less than 500 tons. All of these vessels were steel plated only. Practically, then, steel ship building was an unknown art, the material untried, and the workmen unskilled, when the frame of the "Dolphin" was laid down in 1883.

Such was the status of the steel industries as regards structural material when Congress authorized the constructien of our four first ships of mild steel of domestic manufacture. The courage and foresight of the Advisory Board of Naval Officers, upon whose recommendation Congress acted, are entitled to recognition. Iron ship building was already an established industry, and its results certain. As to steel (this was in 1882), there were difficulties in production, as yet imperfectly understood, and but partly overcome. There was the still more serious objection of the utter lack of workmen skilled in the manipulation and assembling. The compelling reasons leading to the Board's decision are here given:—

1. Great saving in weight of hull, compensating for difference in cost.

2. Increased strength in hull.

3. Increasing success attending construction of steel hulls abroad.

4. The certainty that steel in the near future is to supplant iron in ship construction. (A prophecy virtually fulfilled.)

a voyage of over 45,000 miles around the world. That these ships have shown themselves equal in construction and material to the strains and service for which they were designed has been abundantly proved. During the construction of these vessels a determined effort was made to break down the system of naval tests and inspection. The reasons assigned were impracticability and expense. Delays were not only exasperatingly frequent, but failures also were many. The specification as to ductility was lowered to 21 per cent, and some slight modifications made as to methods. The system then established is the foundation of our present inspection. Each new vessel is built of better material than her predecessor, and the requirements keep in advance of the material. In 1886 the Steel Board succeeded the Advisory Board, and has for its function the inspection of all steel material for hulls and machinery.

Attention was called to tables on the board which showed the increasing severity of the specifications, and the changes due to experience.

In hull plates and shapes we find the tensility constant at 60,000 lbs., but the additional safeguards of chemical conditions and surface inspection, aided by additional tests, serve to show the good or bad quality of the material better than either T. S. or elongation.

Up to 1876 steel was generally accepted on the maker's guarantee. From that time, however, testing of steel, particularly boiler steel, came in. The features of the Pennsylvania R. R. Co.'s inspection, which are quoted as being the most thorough before the navy inspection began, were: —

1. Careful examination of every sheet for mechanical defects.

2. Tensile test; 55,000 lbs. per square inch, ultimate strength. Elongation; 30 per cent in 2 inches. Both of these were averages. The limits were: tensile, minimum 50,000 lbs.; maximum 65,000 lbs.; elongation, minimum 25 per cent.

3. Rejection of sheets developing defects in working.

4. Coupon tests for each sheet.

No conditions were imposed on impurities beyond those which the manufacturer knew would affect surfaces, and cold or hot shortening.

The inspection of steel for naval purposes contemplates that the inspector should thoroughly familiarize himself with the composition of the furnace charges. As the variations in the pig and mill irons,

are pitting, scabs or blisters, hair cracks, scale marks, snakes, cobbles, and laminations. Probably 75 per cent of surface defects are due to pits. Pits are conical cavities, base uppermost, pocking the surface. If their depth is at all considerable the plate is ruined. Their cause has already been stated. Should cinder or fine brick from the heating furnace be rolled in, a spotted appearance will give indication. A sharp tap of the long-handled hammer carried by the inspector will dislodge the extraneous substance, and disclose the extent of the injury. Bits of slag are discovered by hair lines. Scale cools more rapidly than the plate itself, and produces hummocks. Cracks are found in the direction of rolling, and indicate imperfectly welded blow-holes long drawn out. Test transverse specimens to ascertain their injury. Snakes, on the contrary, as their name implies, are twisted in every direction. Their appearance strongly resembles a water mark in paper, and they are visible only in favorable lights. They are, undoubtedly, caused by the presence of low forms of iron, peroxides, or protoxides, generated by burned metal in the furnace, and separate two masses of pure steel. No amount of work, heat or mechanical, will effect a true weld across this filmy barrier. Once in the ingot, snakes reappear inevitably in the plate or shape. An ingot known to be snaked is at once thrown aside to be scrapped. Snaked material is utterly lacking in homogeneity, and no material for structural, boiler, or engine purposes should be accepted which is even suspected of this defect. Crucible and basic steels are nearly exempt from this evil. Radiating furnaces should prevent them entirely.

Laminations occur at the surface and upon the edges. Surface laminations are due to chipping ingots, the cavity thus formed being covered by overlapping edges. A few taps of the hammer will cause these overlaps to separate into sheets. Plates should be inspected for laminations after shearing.

Cobbles are waves in a plate caused by unequal heating of the sides of an ingot. Under an equal draught from the rolls the hotter side creeps faster, thus producing ridges. There is no remedy for this defect. Cobbles are recognized by the diagonal trend of the ridges. Simple waves at right angles to the longitudinal axis are not serious. They are caused by unequal cooling on the train rolls.

SHAPES.—The surface inspection of bulb-beams, angle, T, and Z bars is much simpler than that of plates. The blooms, slabs, or

at bottom end, or 6 per cent. The taper of this ingot gave 26 reductions for top end to 27 reductions for bottom. The elongation fell from 32.7 per cent at top to 29.8 per cent at bottom, or 10 per cent. The value of this plate was evidently the minimum in each case.

The larger the ingot the more essential the selection of specimens from the top. Segregation of the metalloids increases with increase of size, as large ingots, presumably, cool slowly. The temperature at which the heat is termed is, however, of greater importance. Surprising variations occur in chemical condition in same ingot. Thus, two specimens taken from the opposite ends of the same plate rolled from a slabbed ingot, and a slabbed ingot has already lost by shearing its worst end, gave:—

	T. S.	Elongation.	Reduction.	Carbon.	Phosphorus.
Top end, . .	64,500	19 per cent.	31 per cent.	0.31	0.075
Bottom end, .	55,400	26 "	48 "	0.17	0.050
Heat test, ...				0.15	0.044

A result sufficient to condemn at once the material for ship building. In cold bending the top specimen broke short off with fracture, indicating high carbon and phosphorus, and showing weak, large crystals. The bottom specimen closed upon itself without a crack.

TESTING SPECIMENS.—The test piece selected for breaking is carefully measured with a micrometer reading to thousandths of an inch. From this is computed the original section. Twelve one-inch marks are punched on the edges for elongation data. The specimen is then placed in the machine and the initial stress applied. Additional loads of 5,000 lbs. each are added at intervals of thirty seconds, the beam being kept in equilibrium. The elastic limit is marked by unsteadiness of the beam, ending in a sudden drop. The cracking of the mill scale at this instant is a good though not infallible indication. When the ultimate strength is reached the beam refuses to rise. After this the specimen stretches and necks, until fracture occurs, with a sharp report. The fractured ends are carefully fitted together and measured as before. The comparison of these new measurements with those previously taken gives the percentages of reduction of area and elongation. The ultimate T. S. and elastic limit are calculated from original sections. Elongation varies widely with the location of the fractured section. The nearer the grip the less the elongation; the nearer the center of the specimen the greater.

close to the fillet. These beams were rolled from unconditioned Bessemer steel, and the fractures disclosed large, weak, fiery crystals. At present all beams are conditioned in that arch enemy, phosphorus, and the metal must be open hearth. Angles must also open and close without fracture. Few fail in opening, the closing test being the more severe. The present drop or shocking test affords an excellent method of judging of the brittleness.

A 5″ x 3″ x 9′ reverse bar of open hearth steel for the armored battle ship "Maine," now building at New York, endured thirty-three blows from a 640-pound weight dropped 5 feet. The bar inverted after each blow was bent over 90°, and showed fatigue after the twenty-fifth blow. When fracture occurred, the steel tore, not split, half across the narrower angle. At this time the bar had lost all semblance to its original shape, being twisted and flattened. Similar tests made with cold punched bars showed that the fractures rarely extended into the holes, though often grazing them. A better material for ship building can hardly be asked. Hulls framed of such metal will endure any amount of battering, bumping, and ramming before breaking.

BOILER PLATES AND STAYS.—All boiler plates must be of open hearth steel conditioned to .035 of 1 per cent of phosphorus, and .040 of 1 per cent of sulphur. Each plate is tested independently and stands or falls upon its own record. Hull plates are tested by heats. Test specimens are cut both longitudinally and transversely, the transverse specimens showing higher tensile and lower elongation. Owing to the greater size of the ingots, due to large and heavy plates, there is more difficulty in proper heating, the outside frequently bleeding before the core is sufficiently hot. This causes more pits and laminations. Thus, the shell plates for the boilers of Cruiser No. 5 were $\frac{35}{32}$″ thick, and weighed finished 5,000 lbs. each. Ingots for such plates would weigh from 8,000 to 10,000 lbs. The economy of fuel in high pressure boilers has already forced us a long way in increase of strength of material. Our new cruisers, with boilers 15′ 9″ diameter, working under pressures of 160 lbs., show how far we have progressed. The introduction of high tensile, high carbon wide shell plates is not entirely devoid of danger. High carbon means less dependence. Plates over 70 inches wide develop defects which narrower plates escape. We shall be told that wide plates are preferable to

known. Our best boiler steel exceeds the best boiler iron in strength about 18 per cent.

ENGINES.—The use of steel in engines is as old as its use in boilers. We find it in the shafting of the Dover mail packets in 1857. These were of puddled steel. The failures of many Krupp shafts (T. S. 80,000 lbs., elongation in 8 in. 14 per cent) in 1863 greatly retarded further advance. In 1880, however, mild steel (T. S. 50,000 lbs., elongation 20 per cent) was introduced. At present we use a T. S. of 60,000 lbs., elongation in 2 in. 28 per cent, and consider 70,000 lbs. as the safe upper limit. All steel for forgings must be made by the open-hearth process, and must not show more than .06 of 1 per cent phosphorus, nor more than .04 of 1 per cent sulphur. All forgings must be annealed and free from cracks, blow holes, hard spots, and foreign substances. The cost of solid forged shafts is very great, as it requires a 42-ton ingot to complete a 17-ton shaft. The Bethlehem Co. now make shafts up to 30 in. diameter, weighing 40 tons each. The saving in weight over iron is about 36 per cent. At present steel is generally used for shafting, piston and connecting rods, valve and reversing gear, various arms, rods, etc.

Cast steel is preferred for engine frames and bed plates, pistons, cylinder and valve chests, bonnets, cylinder liners, etc. Wherever it replaces iron a saving of at least 25 per cent can be reckoned upon.

For tension and ability to resist shock cast steel is one-third stronger than wrought iron; forged steel three times stronger. Similar relative superiority exists in transverse and torsional strength. The steel castings for the gun-boat "Petrel" gave T. S. 72,196 lbs., elongation in 2 in. 32.5 per cent, reduction of area 35 per cent. Specimens bent cold 116° without fracture, and this is cast, not wrought, metal. The advance in ductility in castings has been very rapid. The substitution of cast steel of a ductility superior to old forgings for moving forged portions is already begun.

ANCHORS AND CHAINS.—The anchors for the navy have cast-steel crowns and flukes with forged iron shanks. The requirements for the steel are, after annealing: T. S. 60,000 lbs.; elongation in 8 in. 15 per cent; phosphorus .06 of one per cent. The weight is practically the same as iron, as lessening an anchor's weight lessens efficiency. The gain in strength exceeds 35 per cent.

We have not as yet secured steel chains for the navy, but the

	T. S. pounds.	El. L. pounds.	Elong. 2 inches.
Tubes, . . .	70,000 to 80,000	33,000 to 38,000	12 to 22 per cent.
Jackets, . .	74,000 to 85,000	34,000 to 40,000	12 to 20 "
Hoops, . .	90,000 to 100,000	45,000 to 50,000	12 to 18 "
Trun. Bands,	80,000 to 90,000	36,000 to 40,000	6 to 12 "

Test specimens are cut transversely as well as longitudinally. "Forgings must be made of open-hearth steel of domestic manufacture, from the best quality of raw material, uniform in quality throughout the mass of each forging, and throughout the whole order for forgings of the same caliber, and free from slag, seams, cracks, cavities, flaws, blow-holes, unsoundness, foreign substances, and all other defects affecting their resistance and value."

The trunnion band is an unhammered steel casting, rough bored and turned, annealed, oil-tempered, and again annealed. It is screwed on and held by a set screw. The elevating band of wrought iron is shrunk on and keyed. All other parts of the gun proper are forged steel. The steel maker is required to discard 30 per cent of the top and 5 per cent of the bottom of each ingot. Tubes, jackets, and hoops are forged from solid ingots and afterward bored. For tubes we require the bored ingot to be reduced 50 per cent in thickness, and for plugs and mushrooms the same. Jackets must be reduced 33 per cent, and hoops at least 30 per cent. All forgings, after forging is completed, must be annealed, oil-tempered, and re-annealed. Tubes, jackets, and hoops are forged closely to dimensions and afterward bored.

Without entering into the details of gun construction it will suffice to state that over the tube is shrunk a heavy jacket, about one-third the length of the tube. From this jacket to the muzzle are shrunk a series of lighter hoops. Outside the jacket are again shrunk a row of heavy hoops constituting a second reinforce over the powder chamber and the seat of the projectile. The breech-loading apparatus, of the interrupted screw type, locks into the rear end of the jacket.

By the method of shrinkage, the bore in all the new guns is compressed nearly to its elastic limit, *i. e.*, about 35,000 lbs. The actual diametrical compression rising from 0.005" at the muzzle to 0.016" at the rear end of tube.

All calibers have about the same strength, though the larger have a *greater factor of safety* than the smaller ones. Slower burn-

rifling was done at the Washington navy yard, and the gun taken to Annapolis for trial. The conditions imposed ten rounds in quick succession, and the charge sufficient to ensure a muzzle velocity of 2,000 feet per second for a 100-pound projectile. A preliminary warning charge having been fired, the gun was loaded with forty-eight pounds of brown prismatic powder and projectile. The gun went to pieces abaft the trunnions, the bursted segments completely wrecking the heavy 12-inch timbers built over and around it. The breech mechanism was found intact. The pressure gauge indicated fourteen tons. As the usual energy of such a charge is fifteen tons, it is evident that the walls of the gun gave way before the gasses had been fully evolved. The physical characteristics of the metal were: —

	T. S. lbs.	El. L. lbs.	Elong. in 2 in.
Breech long., . . .	89,686	51,693	9.75 per cent.
" trans., . .	73,236	57,290	0.60 "
Muzzle long., . .	81,185	40,461	18.00 "
" trans., . .	79,174	41,500	16.50 "

The wide variations and almost total absence of elongation in the transverse breech specimen are full of significance. As the gun was cast breech up of indifferent metal, with an utterly insufficient sinking head, the reason for the unsatisfactory breech specimen appears. A chemical analysis of the borings constituted as good an instance of lack of homogeneity and marked segregation as exists. The failure of this gun shows that poor steel, badly treated, cast without safeguards, tempered by a process as unusual to good metal as to the maker, will not bear strains that call upon the best steels for all their elasticity and strength.

The second gun was of open-hearth steel, of good metal, cast by a company of acknowledged merit, with every precaution their large experience could suggest. This gun withstood the ten rounds without apparent injury, but the star gauge developed serious enlargement of the bore. The elastic limit had been exceeded, and the gun ruined for ordnance purposes. In Sweden, however, guns up to 5.2-inch caliber have been successfully cast and successfully fired. It is useless to go over the arguments of built-up versus steel cast guns. Certainly, the advocates of the built-up guns have the best of the facts. I hazard little, however, in believing that the question may assume a different

of-war, armed with powerful guns, capable of sustaining the dignity of a great power, is the least of the advantages reaped by the nation. The direct service to every mechanical trade has already returned to the people the prime cost of the new navy.

MEETING 401.

The Application of Storage Batteries to Street Car Propulsion.

BY COL. E. H. HEWINS.

The 401st meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, March 27th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, and the election of new members, the President introduced Col. E. H. Hewins, general manager of the Union Electric Car Company, who read a paper on "The Application of Storage Batteries to Street Car Propulsion."

COL. HEWINS said: The question of street transportation is one that more nearly concerns every individual in the community than almost any other, and its solution is one that has occupied prominently the attention of engineers in all ages. The modern horse car is the result of the accumulated experience of ages, but now the demand is for something still better. In this service is invested immense capital, it furnishes employment to thousands, it serves millions, and comes into most direct contact with the masses.

Here is the opportunity, and perhaps here more than anywhere else is to be wrought out the old problem of the proper relationship between capital and labor, and state or corporate ownership. The signs of the times already indicate this latter to such an extent that all should take note of passing events, and the Nationalist says the community must address itself to the solution of this momentous question.

lessly, carelessly, or ignorantly used, a very costly horse may be quickly and seriously injured. So far as I have been able to learn, with one exception, the employment of storage batteries for street car work has thus far required a drain greater by far than any maker ever claimed to be their ability to deliver. The result has been the prompt destruction of the battery.

It may be well to interject here some of the characteristics of storage batteries, though not with any purpose to undertake a thorough description of this peculiar agent. I gather from the different details of construction shown by different makers that in one respect they may be separated into two classes,—one constructed upon the theory that as much *surface* of plate as possible should be exposed to the solution, and the opposite that *mass* of active material is the desired object.

Your attention is directed to the several elements shown on the table, which illustrate these two extremes to a great degree, as well as other characteristics. In one you will observe that the plates are thin and placed near together with as many plates as possible, giving large surface in contact with the solution in which the plates are immersed; while the other is constructed of thick plates placed far apart, thus exposing comparatively small surface to the solution, but containing large mass and large surface between the active material and its carrying lead plates, which is claimed to be desirable. Again, we see a pile constructed upon quite a different principle. Its active material is not made in the form of a paste, paint, cement, or powder; but is melted and cast, so that it exposes more surface to the solution than either, and is claimed not to deposit or waste away in use.

I also understand that the nearer together the plates can be put without touching the better, provided they can be secure of parallelism. In two of the piles here shown is a marked peculiarity to which I would call your attention, *i. e.*, the one that is mechanically the most certain of remaining in position has double the space between its plates that is exhibited in its competitor.

However it may be obtained, whether by small space between the plates, by large amount of surface exposed to solution, by large mass of active material, or by large surface contact between active material and its carrying lead plates,—the desired objects to be secured are low internal resistance and capacity.

In addition to the saving of energy and repair is the fact that the truck rides much easier, not being rendered stiff by the gearing and counter-shaft,—quite a difference in the agreeable riding of the car, and also, what is more important, an absence of noise from the gears, which, when considerably worn in the systems with which you are familiar, is very excessive; so that conversation is difficult. No doubt many of you have noticed that when new cars or lines are started the noise is very much less than after being run a few months. This is very largely due to the wearing of the gears.

Another important feature of Mr. Stevens's invention is called the "recharging" device. This invention consists in rendering a series-wound machine, either a motor or dynamo, as the occasion may call for, without the necessity of human intelligence or action. The possibility of doing this without mechanically reversing the field connections, and the application for a patent, were denied, and it required quite an effort to convince the Patent Office that it was being done daily. It simply consists of a few cells of battery put into a shunt circuit with the field coils. The result without these supplementary cells is that when the car tends to run faster than the position of the switch handle indicates is desired, the counter e. m. f. becoming equal to that at the binding posts, no current flows, and consequently there is no magnetization of the field magnets; but with the elementary cells the field is kept charged in the right direction, and immediately the speed has increased beyond the desired rate, the machine driven by the car generates a current in the direction opposite to that which drives it as a motor, and the current so generated is returned to the batteries or to the line as the case may be,—for it is to be understood that this system is equally applicable to storage battery, to overhead or underground conductors, or to a combination of the two. For instance, there are places where overhead construction might be unobjectionable and even desirable, but on a continuation of the same route inadmissable. In such cases the car would habitually be started with current from the battery, and after having attained a proper speed be switched onto the trolley, and while so connected the battery would be charged. When the end of the trolley wire is reached, the car would be run over the balance of the route entirely with current from the battery until its return to the trolley wires.

Cars equipped with this system are habitually run down hill, and

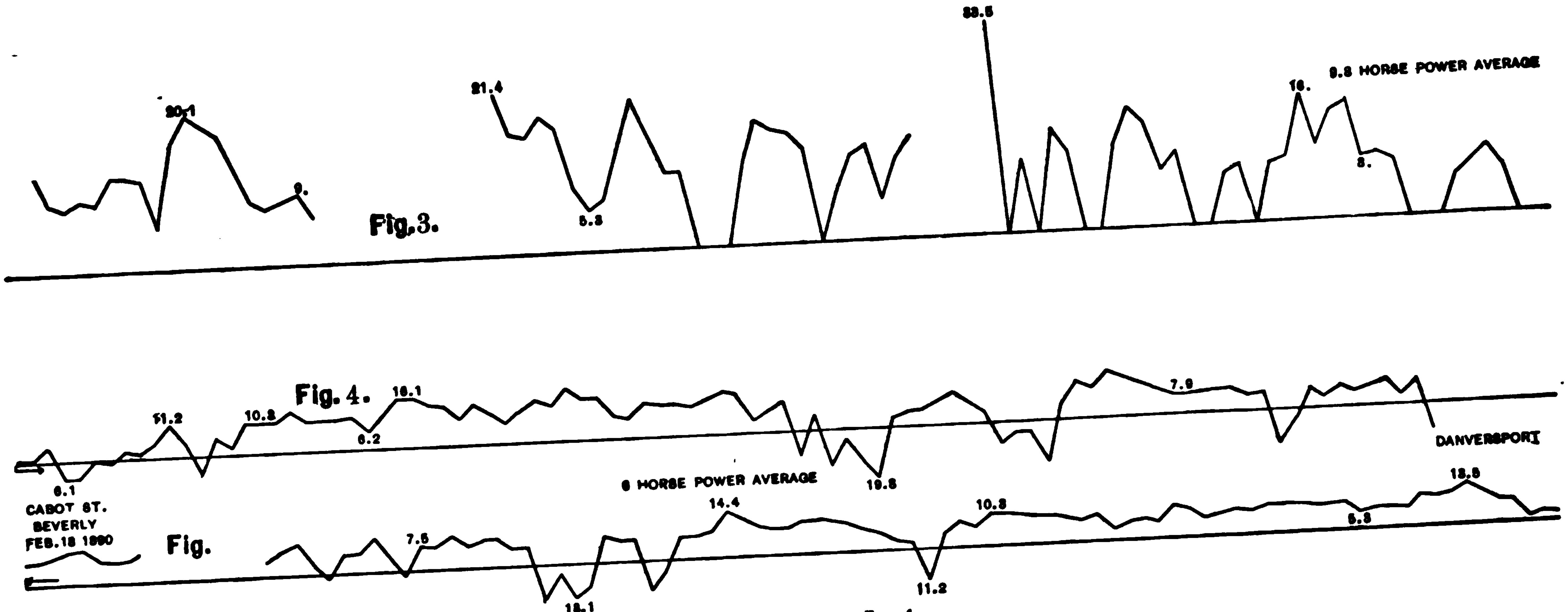


Fig. 3.
9.8 HORSE POWER AVERAGE
20.1
9.
21.4
5.3
33.5
16.
8.
Fig. 4.
6 HORSE POWER AVERAGE
DANVERSPORT
CABOT ST.
BEVERLY
FEB. 18 1890
Fig.

Figs. 3 and 4.

PROF. THOMSON said: The study of alternating currents and the effects of such currents in producing fields of magnetic influence has been greatly stimulated by the industrial development taking place with alternating currents in electric lighting. In particular, the phenomena occurring as a result of induction and self-induction have opened to us very many interesting fields for study and investigation. The consideration of the action of displacement of phase due to induction or self-induction, as the result of a retardation or lag brought about by such induction or self-induction, has been particularly interesting and fruitful. Much light has been thrown upon the more obscure actions occurring in ordinary electrical apparatus using continuous currents by the analogous but more pronounced effects obtained with alternating currents. The subject of losses due to magnetic friction or hysteresis has been and is receiving careful study in the hands of some of the ablest electricians. The revival of the almost forgotten idea that the static spark or Leyden jar discharge is an alternating discharge at a very high rate or speed of reversals has not only assisted in our general understanding of electrical actions, but has borne fruit, it may be truly said, in the experiments proving that light and radiation are phases of electrical action,—not, as I have seen seriously discussed that light and electricity are one and the same thing, but that light and radiant heat are related to the science of electrical undulations or vibrations. It becomes simply, then, a widening of the electrical field to cover light and radiation, not a question of identity in all respects.

In the same way I anticipate eventually that we may learn by experimental research, coupled with theoretical considerations, that conduction of electrical current is not different from electrolysis in essence, except that the interchange of atoms in molecules of the conductor replaces that occurring in the electrolyte, and where the conductor is a solid a restriction of the decomposing and reforming molecules to definite positions occurs, while in the electrolyte the newly formed molecules are freer to move, and may therefore take new positions.

I anticipate, further, that we may learn that the warming of a body absorbing light or radiant energy is a result of almost infinitesimal closed electric circuits, just as the warming of a copper plate exposed to magnetic waves is due to electric currents on a larger scale. It may be possible also that we may learn to regard atomic move-

waves of current in the conductor. There is, however, a strong repulsive effort exerted upon the closed coil, band, etc., when it is of such size and material as to have the currents induced subject to great self-induction. If the currents induced lag or are retarded, they become opposite in direction to those which produce them, instead of alternately opposite, and in the same direction. The currents induced tend to maintain a magnetic field of opposite direction of polarity to that of the inducing currents or field at any instant. If the closed coil or secondary band exerts by the currents induced in it a controlling effect upon the magnetic field, such that the normal directions of the magnetic lines set up around the inducing coil are greatly distorted, the repulsive effect is strongly produced, and can forcibly thrust the ring or band away from the coil, or it may balance the ring for a moment in free air (Fig. 1). Could we obtain a condition of stable

FIG. 1.

FIG. 2.

FIG. 3.

equilibrium in this case the ring would remain suspended, but the condition is one of unstable equilibrium, and the ring or band can only float securely above the coil when stayed at one side by horizontal strings.

Plates and discs of copper are likewise repelled or sustained. When one ring of copper is held in suspension above the coil or pole by alternating currents, another ring may be added and is supported closely parallel to the first ring, in virtue of the agreement of direction of the induced currents in both rings, which causes attraction, or makes them act as one ring. Too heavy a mass of copper, such as a heavy copper plate, will, however, cut off or so far distort or reflect the magnetic lines as to nullify their effects on a ring placed above the plate. This is exemplified very easily by substituting for the ring a

provided with the usual shunting switches. I have found also that the regulation may be obtained by governing in a similar manner the reaction or self-induction of the primary itself, or the primary current may be caused to traverse a series of lamps and a reactive coil, and the secondary coil or band be simply a partially balanced closed circuit, movable automatically to change the self-induction of the reactive coil, of which it is the secondary. It will be seen, then, that the repulsive action can be used practically in regulation of alternating current. Very good and effective practical measuring instruments, as well as alternating motors, have been based on the same principles of obtaining movement from such currents. Our time does not here permit a description of these. The regulating mechanism of arc lamps for alternating currents can equally well embody the repulsive devices of the closed band or circuit, and a coil in circuit with or in shunt to the arc.

We have shown the experiment of causing two rings to be attracted and held together while subjected to the alternating field. If we substitute for one of them a disc of copper (Fig. 5) pivoted so as to rotate easily, or a disc of iron likewise pivoted, we can, on variously placing the closed ring and disc in the field, obtain brisk rotation of the disc. A plate of copper or brass may be substituted for the ring, and, in fact, any closed conducting plate or piece of metal may be used. The action is due to the formation of parallel currents, or harmonizing and attracting fields, where two copper pieces are used, and to retention of magnetism or hysteresis where one of them is of iron.

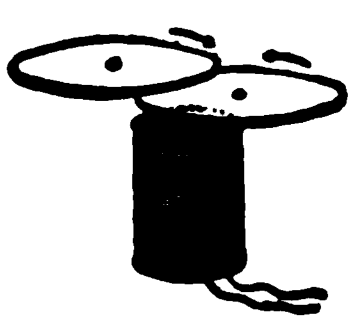


FIG. 6.

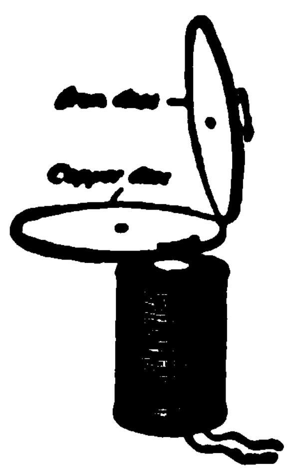


FIG. 7.

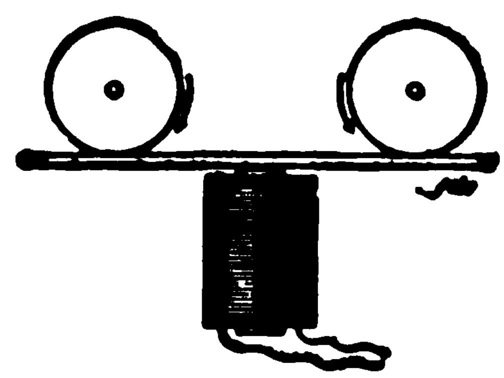


FIG. 8.

I would say here that Mr. M. J. Wightman and myself have carried on these experiments to a considerable extent, and amplified their effects in many ways, constructing motors, regulators, etc. based

A curious experiment, combining the effects of closed circuits around cores and hysteresis, or resistance to magnetic change, is seen in the use of a cast-iron ring, on one part of which is wound a small coil of copper wire, closed on itself. When this is laid down so that the part of the ring near the closed coil rests on the alternating pole, and the pivoted iron disc is held near the center of the ring with its plane parallel to that of the cast-iron ring, there is noticed a rotation of the disc in a direction coinciding with propagation of magnetism around the ring, from the inducing pole along that side of the ring on which the closed coil is not wound, said coil appearing to shield or cut off its propagation in the other direction around the ring. The currents developed in the closed coil beat back the magnetic lines, while they remain free to move along the uncovered portion of the iron ring, and so drag the disc around also.

By taking advantage of the principles set down we may construct a simple motor, such as is here seen. A ring of laminated iron has a slot cut through at one part. The rest of the ring is wound with insulated wire through which an alternating current may be sent (Fig. 9). The sides of the slot or pole faces are partly shaded or

FIG. 9. FIG. 10.

shielded by copper circuits affixed thereto on the upper part. The effect of this is to retard the development and change of polarities in the upper part of the opposed pole faces, and leave the action unhindered in the lower part.

Placing a copper disc mounted so as to be easily rotated, with one part of its edge in the slot, there results a vigorous rotation of the disc and the exertion of some torque. Removing the disc, we may

A very good device for supplanting the copper and iron discs in some of the experiments is a combination of the two. A small shaft has some thin iron washers strung on it at the center, and around the edge of the iron discs is placed a copper ring or band, forming an overhanging rim like a pulley rim. The shaft is hung in a suitable frame to allow the device to be handled.

Placing a wedge-shaped piece of iron on the alternating pole, and with its edge upward (Fig. 13), we may bring the induction wheel, just described, near the edge, but to one side of it, and we will obtain brisk rotation of the wheel. On the other side of the edge the rotation is reversed. The action is due to the same cause as was found

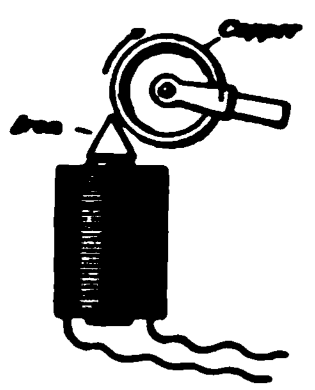


Fig. 13.

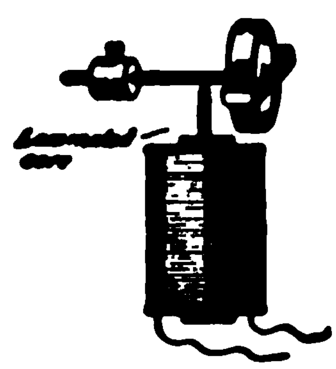


Fig. 14.

in the case of the steel file, though it is a curious modification, inasmuch as the appearance is as though something passed off the edge of the wedge, and blew the wheel around.

I have reserved for the last instance of these actions the case of a gyroscope of novel construction (Fig. 14). The wheel is like that just described, but it is mounted on pivots borne in a copper frame surrounding the induction wheel, which frame is in turn provided with a bar for pivoting and for a counter-balance weight. The instrument thus constituted is hung on a pivot placed in the center of the alternating magnet pole and held for a few moments, during which the wheel gets into rapid rotation. It is then capable of exhibiting all the well-known gyroscopic actions, which are a stumbling block to beginners in the study of physics, and than which nothing could be more simple and easy of comprehension when the true meaning of the actions is grasped. It is, indeed, curious to notice that in this electric gyroscope we have the electric rotations obtained, no doubt, from a direct absorption of ether energy or wave motion, without connection, electrical or mechanical, and that they are obtained altogether inde-

not excite even passing notice. But it is the "what may be" successful systems that are now on trial there which the whole scientific world studies with interest. Activity in the promotion of companies to supply electric lights is of comparatively recent date, and it is only within the past year that the public has sought electric light stocks for conservative and legitimate investment.

Great Britain far surpasses us in legislation and red tape. In 1882 a few central stations were projected, and several cities and towns that were suffering as they thought under the burdens of private corporation gas monopolies were indirectly the cause of the passage of an act by Parliament, whereby electric light stations could be bought by municipalities after 21 years at the assessed valuation of the apparatus. Successful ventures could last 21 years; failures or partial failures would alone remain in the hands of private companies. The municipal control of gas works is common in England, and perhaps as successful as private enterprises but no more so. Private capital did not come forward very freely. Too much legislation had blocked the way, and, with the exception of a few experimental ventures, electric lighting was forgotten. In 1888 the time for the purchase of a plant by the local authorities was extended to 41 years, and some other concessions granted that made electric lighting possible, if not profitable.

To erect overhead wires a "license," *i. e.*, public consent, must be obtained, and of course where buildings are used for structures private consent as well; but as poles in the streets are rapidly excluded, the somewhat expensive and temporary system of housetop circuits did not find favor, except in a few instances, although all companies employing overhead wires exclusively were not subject to the selling out clause in the law of 1882. To obtain the right to open streets and lay underground mains a provisional order must be obtained, and this subjected the company to the danger of being bought at the end of 21 years by the local authorities.

After the change in the law in 1888 there was a boom; systems almost without number had been invented, and some perfected. To try each on a working scale many were ready to supply money, and by the end of last year 179 applications had been sent to the Board of Trade for provisional orders, one-third of which were from local authorities.

The plant consists of three Siemens shunt-wound dynamos, running 350 revolutions per minute, and connected direct to Willans triple expansion engines, the exhaust steam being condensed in heating the building, passing through two heaters, one warming the water for heating the building, the second for the feed water. Pumps for water supply and elevator are in the engine room, where there is also a large tank for softening water. A fan operated by a steam engine exhausts air into the flue and reduces the temperature 15 degrees, which is 100° at the least calculation. In the Garrick Theatre there are 8 batteries of 44 cells each, charged with only 33 in series, when there are of course 10 sets. The Elwell-Parker type of cells is used here as well as at the station, and furnishes current while the engines are not working from 12.30 M. to 7 A. M. Two 8 sets of batteries, of which one-half are used every other day, can discharge, combined, 1700 amperes. Pilot wires are run to the station from the most distant points of the underground mains about one-half mile away. 100 volt lamps are used except in the theatre. The E. M. F. at the dynamos is 108 volts. Hand regulation is satisfactory with the engines. Three single-ended internally-fired marine boilers supply steam. The roof is formed of iron trusses supporting the paved street above. This station is worthy of notice as deserving a diploma for the hottest engine and dynamo room. It is a wonder that the storage batteries are not injured.

The reason assigned for the apparant want of success with storage batteries in this country, especially in New York and Philadelphia, is, according to English engineers, the excessive heat, but in this room they are operated in an atmosphere at a temperature not far from 100 degrees.

At Rathbone Place, Waterloo Bridge, Manchester Square, 1000 volt alternating stations were under construction. One at Sardinia Street, near Lincoln's Inn Fields, was completed last September. The interior is un-English. There are four 2500 light dynamos driven by compound engines made in this country, and are as much reason for congratulation as any of the notable victories by American scientists and manufacturers. At any rate, American electric lights have been so well liked that the original plant has been more than duplicated. The chimney of this as well as of the Rathbone Place station and many others is built with white enameled or glazed brick on the

Ascending from this basement by a winding iron staircase, a floor is reached, designed for accumulators. The next floor is filled with carriages, and the upper one with offices. The final capacity of this station has been carefully considered in its design, and is 13,200 horse-power or 2000 light dynamos, and by the aid of accumulators 50,000 lights can be supplied. All foundations and steam and exhaust pipes have been laid for the full capacity. The mains and feeders are bundles of bare copper strips in 150 feet lengths stretched tight with tackle and soldered, and supported at the ends of each section of conduit. This is of U shape, the sections being joined by iron saddles, caulked with lead. The cover fits into grooves, and is made water tight with hemp and red lead. At each saddle a porcelain separator with three grooves contains and supports the conductors. As the sections are about 10 feet long, ebonite separators are also placed on top in each section. Attachments are made by drilling, tapping, and bolting the house mains to the street mains. At low points the conduits and junction boxes are drained. The coal used in this station costs delivered 24 shillings, or $6.00, per ton. The best Welsh navigation or smokeless coal must be used in London, and this, with the coal dues and expenses for teaming, makes the fuel bill more of an item in the expense account than would be the case with us if more economical engines were used. A second station is proposed in the northern portion of the district near Oxford Street.

The Kensington & Knightsbridge Company have at Kensington High bridge a station now in its fourth year, engineered and designed by Mr. Crompton. 7000 lamps were connected in July, and at the time of my visit, 6 P. M., with three hours more of daylight, the output of 50 amperes indicated that 100 lamps were in use. Three 90 horse-power Willans engines and three 550 ampere Crompton dynamos, and 2 sets of the Howell accumulators of 60 cells each formed the working plant. In July the starting hour is 7 P. M., and the machinery is stopped at 1 A. M., or when the cells become fully charged. During the remainder of the 24 hours the batteries supply current. These have an output of 100 per set. The batteries simplify regulation. The plant was being more than doubled in size, and Babcock and Wilcox boilers of 250 horse-power were being added. Other generating and storage battery stations are in process of erection or contemplated to supply this district. The cost of producing 1000

measure the current consumed. It is intended to make use of the Edmunds' distributing system, wherein the batteries in consumers' houses are divided in groups and charged a portion at a time, the switching being effected by a small motor. The system is unique, and, under the supervision of the managing director, J. S. Sayer, may supplant earlier systems. The "Leeds" dynamos give 400 volts 70 amperes, have Gramme ring armatures and run at 800 revolutions, and are belted direct to Armington and Sims engines, 50 horse-power built, as well as the dynamos, by Greenwood and Batley.

Years ago in England all large powers were transmitted by gearing, and it was thought impossible to use belts. This prejudice had exercised great influence in the introduction of direct coupled engines, and has almost entirely prevented the use of leather belting. So, in this station the leather belts and American engines and boilers of the Babcock and Wilcox type reminded one of home. In this station boilers, engines, and dynamos are in one large room. Three sets of accumulators, A, B, and C, of nine cells each supply 66 amperes for exciting the field magnets of the dynamos, and are charged at the same time they energize the fields. The Worthington steam pumps, in fact, everything, is American except the dynamos and cables. The cables are composed of 19 strands of No. 14 wire, with double rubber insulation, and suspended from iron fixtures on housetops and a few poles. The length of the three circuits is 9 miles, 1000 yards being under ground in plain iron pipes. Engines are started at 6 A. M., and stopped at 9.30 P. M. One circuit is charged in the morning, second in the afternoon, third in the evening. Three thousand lights are connected, and an increase ordered. $12.50 per year per light is charged in bar-rooms, $6.25 for private homes, or by meter at 15 cents per unit. The iron stack, stayed and guyed as if to last for a century, must be taken down in two years, and a brick one built. Iron stacks or chimneys are not quite English. Coal used is the best Welsh smokeless, and costs 23 shillings per ton. The cells always contain two days' supply, but are charged to the gassing point daily. Substations of batteries will be placed in stables behind the best houses, sufficient quarters costing $75 per year. The overhead wiring is well done, the cables supported by leather from galvanized wires attached to glass insulators.

The Chelsea Electric Supply Company has adopted a system of

steel. Copper tube for the entire steam piping is common practice in England. The temporary partition of corrugated iron at the end will give room for nine more boilers in addition to the three now in use. The chimney is large enough for six. All exhaust piping laid under the floor is large enough for 12 boilers. The three engines are compound non-condensing of the Corliss type, and belted to the dynamos by seven separate ropes. They are steam jacketed, and with 140 pounds of steam develop 250 to 300 horse-power.

The Lowrie-Parker dynamos have revolving fields and stationary armature and make 350 revolutions, producing 60 amperes at 2000 volts. The exciters are driven from a small counter on the armature shaft. The details of this system are well worked out. The dynamos are often run in parallel, a feat not attempted elsewhere. To determine when two dynamos are in step a lamp is connected to two secondaries in series, the primaries being one in the circuit of each machine. When the phases of the two dynamos coincide the lamp burns brightly, and the switches are then thrown. The mains are under ground, of stranded wires insulated with india rubber.

All of the stations described thus far in London are removed from supplies of water for condensing purposes, and where coal of extra quality must be used to prevent smoke nuisance. To attain the high degree of economy in condensation, to avoid the expense of carting coal, etc., the London Electric Supply Company located a station at Deptford, five miles from the city, to which a current of 10,000 volt alternating will be carried in concentric cables running by the viaduct of the South Eastern Railroad and the Underground Railroad to substations at Charing Cross, etc., and there transformed to reduce the pressure from 10,000 to 2500 volts, which is distributed by underground mains in bitumen conduits to consumers, and again converted to currents of 100 or 50 volts. So gigantic an experiment as this was not entered upon by chance. A small station in the basement of Grosvenor gallery became a success a few years ago when Mr. Ferranti's system was adopted. Over 30,000 lights are run from this station. The mains are overhead on housetops. The E. M. F. employed is 2500 volts, so that the Deptford installation is not wholly experimental. The saving in the cost of coal is as 22 shillings to 8 shillings 9 pence, or as from $6 to $5.50 to $2.18. The engines now operating are upright marine compound condensing Corliss, working

MEETING 404.

The Engineering Building.

BY PROFS. F. W. CHANDLER, G. LANZA, G. F. SWAIN, AND MR. S. H. WOODBRIDGE.

The 404th and annual meeting of the SOCIETY OF ARTS was held in the Engineering Building of the Institute on Thursday, May 8th, at 8 P.M., President Walker in the chair.

After the reading of the records of the previous meeting the report of the Nominating Committee was presented, and officers were elected for the ensuing year.

The report of the Executive Committee was read and ordered placed upon the records. The President then announced the subject of the evening to be the New Engineering Building of the Institute, and introduced Prof. F. W. Chandler, who described the architectural features.

Prof. CHANDLER said: The Engineering Building of the Institute of Technology is built on Trinity Place, a short distance from the other buildings of the Institute. The structure measures 148 feet by 52 feet, and has six stories. Its height of 85 feet is the extreme limit allowed by the building laws when a wooden construction is used. Its position on the lot was very carefully considered in regard to future additions to the south on the property of the Institute; and, by mutual agreement with the abuttors, there will always be a clear area of 30 feet to the north.

The scheme of the building is what is known as modern mill construction. A row of cast iron columns, placed eight feet from center to center, runs lengthwise of the building, giving spans of twenty-four feet from column to wall. The strength of the brick wall is concentrated in buttresses opposite the columns, and thinner walls unite them, and because these thinner walls are not necessary for the stability of the building, the greater part of this space is occupied by windows, the heads of which extending between the beams, as there are no ceilings, to the underfloor gives that high light which is the most effective in lighting a large room. A pair of southern pine beams extends from each column to each side wall. These doubled beams

columns resting on each other have their ends carefully turned in a lathe to ensure perfectly accurate bearings,— the head of one column having a seat countersunk $\frac{1}{4}$ inch to receive the foot of the next column. In the mill proper these columns are of wood, but, on account of the great weight to be carried in this structure, much valuable space could be saved by using iron.

The beams of the basement floor measure each 11 inches by 18, those of the first floor 10 inches by 18, those of the second 7 inches by 16, and those above 6 inches by 16, and those of the roof 6 inches by 14.

There are no boilers in this building, the steam for heating and for power is brought from the boilers in the basement of the Rogers Building, about a thousand feet away, through a six-inch pipe buried under ground. The pipe is first wrapped in asbestos, and for further insulation it is inserted in a wooden log.

The heating system is partly direct and partly indirect, and with the indirect part ventilation is obtained by means of a Sturtevant blower. Nearly all the radiators have automatic valves, the temperature of the room regulating the steam supply to the radiator.

In connection with the heating should be mentioned that the window sashes of the north, east, and west sides of the building, and also a large skylight on the roof measuring 80 by 16 feet, lighting the upper draughting room, are double glazed, making a great saving in the expenditure of heat.

The exterior design is very simple, all effect being obtained by the principle of construction. The solid basement from which rises the long buttresses or pilasters, connected at the top by semi-circular arches, and the upper story with its thinner wall forming an attic, describes the design. And it is effective enough; it tells its story truly. The material is rough brick with a small amount of long meadow stone trimmings.

A heavy block granite foundation rests on 725 piles, averaging 40 feet long. All the heavy machinery in the basement have their piled foundations distinct from that of the building.

There can hardly be a more fire-proof structure. First, its isolation; then there is not a concealed space anywhere, no furrings on the walls,— the brick is the only finish, no ceilings, with its dangerous air space the depth of the floor joists,— the staircase is built open in

First. To give the students practice in such experimental work as any engineer is constantly liable to be called upon to perform in the practice of his profession,—as boiler tests, engine tests, power determinations, etc.

Second. To give the students some experience in carrying on original investigations in engineering subjects with such care and accuracy as to render the results of real value to the engineering community.

Third. By publishing from time to time the results of such investigations, to add gradually to the common stock of knowledge.

The two lower floors of the building are entirely devoted to the Engineering Laboratories, thus increasing their capacity from about 5,550 square feet, as in the Rogers Building, to about 13,900 square feet. Cuts of these laboratories are shown here, and the following statement of the apparatus they contain is copied from the twenty-fifth Catalogue of the Institute: —

"The laboratory for testing the strength of materials is furnished with the following apparatus. An Olsen testing machine of 50,000 pounds' capacity, for determining tensile strength, elasticity, and compressive strength. A testing machine of the same capacity for determining the transverse strength and stiffness of beams up to 25 feet in length, and the framing-joints used in practice. Machinery for the measurement of the strength, twist, and deflection of shafting while running and under the conditions of practice. Machines for time tests of the transverse strength and deflection of full-sized beams; for testing the tensile strength of mortars and cements, and of ropes; for testing the effect of repeated stresses upon the elasticity and strength of iron and steel; for determining the strength and elasticity of wire; for determining the deflection of parallel rods when running under different conditions. Also, accessory apparatus for measuring stretch, deflection, and twist.

"The steam laboratory contains,—a triple expansion engine, with cylinders of 9 inches, 16 inches, and 24 inches diameter respectively, and 30 inches stroke, arranged in such a way as to be run single, compound, or triple, as desired for the purposes of experiment. This engine is of the Corliss type, and was built by E. P. Allis & Co. It will have a capacity of about 150 horse-power when running triple, with an initial pressure of 150 pounds in the high-pressure cylinder. It is connected with a surface condenser and all the other apparatus necessary to adapt it to the purposes of accurate experiment.

THE HYDRAULIC LABORATORY.

At the close of Prof. Lanza's remarks, Prof. G. F. Swain was introduced, who described the Hydraulic Laboratory.

Prof. SWAIN said: The erection of the new engineering building of the Institute of Technology, to be occupied by the departments of Civil and Mechanical Engineering, offered an opportunity for a considerable extension in the Engineering Laboratories, and an attempt has been made to improve this opportunity by laying the foundation for a laboratory for hydraulic experiments, which should be so arranged as to permit of the carrying out of any experiments in hydraulics which it is practicable to perform within walls. Hydraulic experiments on a large scale must necessarily be performed out of doors, since the measurement of large quantities of water requires apparatus and appliances which cannot be accommodated within walls. Thus, the weir experiments of Mr. Francis, at Lowell, were made by taking the water from one of the canals, and using a lock as a measuring basin; those of Messrs. Fteley and Stearns, at South Framingham, were made by using a portion of the Sudbury River Aqueduct as a measuring basin; the orifice experiments of General Ellis, at Holyoke, were made in connection with the fall between two levels of the canal at that place; and the recent elaborate and careful experiments by Mr. Freeman on the flow of water through fire hose, the discharge of nozzles, and the height of jets, were made at Lawrence, where the hydrant system of one of the mills, as well as the city water supply, could be made use of.

But while experiments such as these are clearly excluded from among those which can be made in connection with a hydraulic laboratory in an institution of learning, there remain a large number which can properly be conducted within doors with the aid of suitable apparatus, and which, though they may be on a small scale as regards the quantities of water employed, nevertheless offer a large field for scientific investigation. The new laboratory of the Institute, as already stated, has been planned with a view to affording opportunity, as the work is extended, for carrying on any experiments which are thus practicable; that is to say, in the following directions: —

1. Experiments on the flow through orifices of small size, both free and submerged, and either sharp-edged, rounded, or fitted with

In the lowest course, a man-hole 24 inches by 12 inches at M; at P, a flanged nozzle with elbow for connecting to 10-inch standpipe, as shown in Figure 15.

In the second course, a 10-inch orifice at G, a second at F, a third at D, and a fourth at C. The orifice at F may be used, if desired, for connecting with a small turbine placed below the floor. That at G is for experiments on submerged orifices. Those at D and C are for experiments on free orifices, or for connecting lines of pipe with the tank. Enclosing the orifice at G, an angle-iron and two bent plates are attached to the side of the tank, as shown, to which a wooden tank extending horizontally and resting on the floor is to be attached. In this wooden tank will be placed a weir, and the water will flow through the submerged orifice at G, or through a submerged mouth-piece, either inside or outside, and either converging or diverging, and will then flow over the measuring weir. The orifice C is fitted for experiments on free orifices, as will subsequently be described. The orifice D is to be fitted with a piece to which pipes can be attached as desired, thus enabling the losses of head at diaphragms, valves, curves, etc., to be studied. On the same level with the orifices D and G connections are made for mercury gauges.

In the third course, a $1\frac{3}{4}$-inch orifice at G″ and another at C″, nearly above the large orifices G and C. These small orifices are for the shafts of the hand-wheels for raising the gates over the large orifices, as will presently be explained.

In the fifth course, orifices similar to those in the second course; and in the sixth course, orifices similar to those in the third course; thus rendering it possible to carry on experiments simultaneously upon two floors of the building. The top of the tank is provided with a flanged nozzle for connecting with the 10-inch standpipe, as shown in Figure 15.

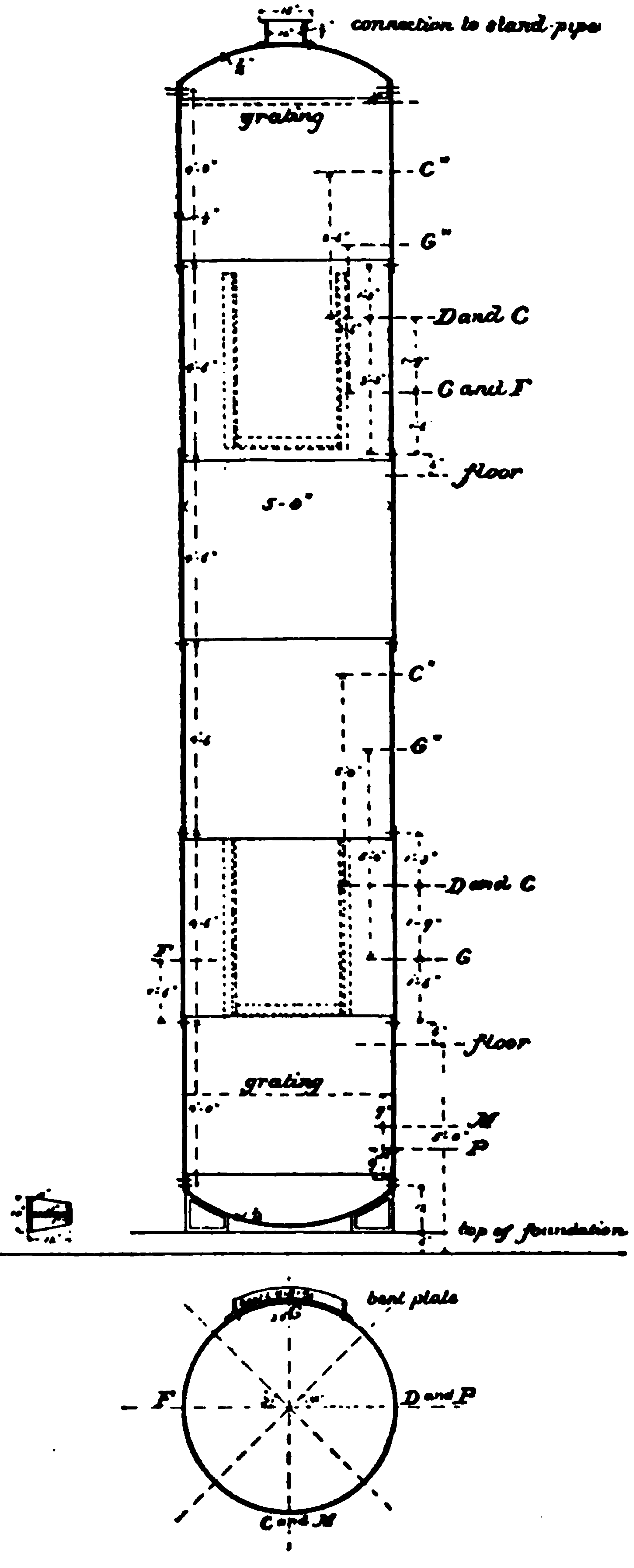
The size of the tank is such that, with the orifices which it will be practicable to use, the velocity in the tank will be so small that it may be neglected, and the disturbance due to the inflowing water from the standpipe will also be small. Nevertheless, two gratings have been arranged, one at the top and one at the bottom. These gratings consist of plates of $\frac{1}{8}$-inch iron perforated by $\frac{1}{2}$-inch holes about an inch apart. They are made in three pieces, and rest upon angle-iron brackets riveted to the inside of the tank. The tank itself rests upon cast-iron supports, as shown in Figure 1.

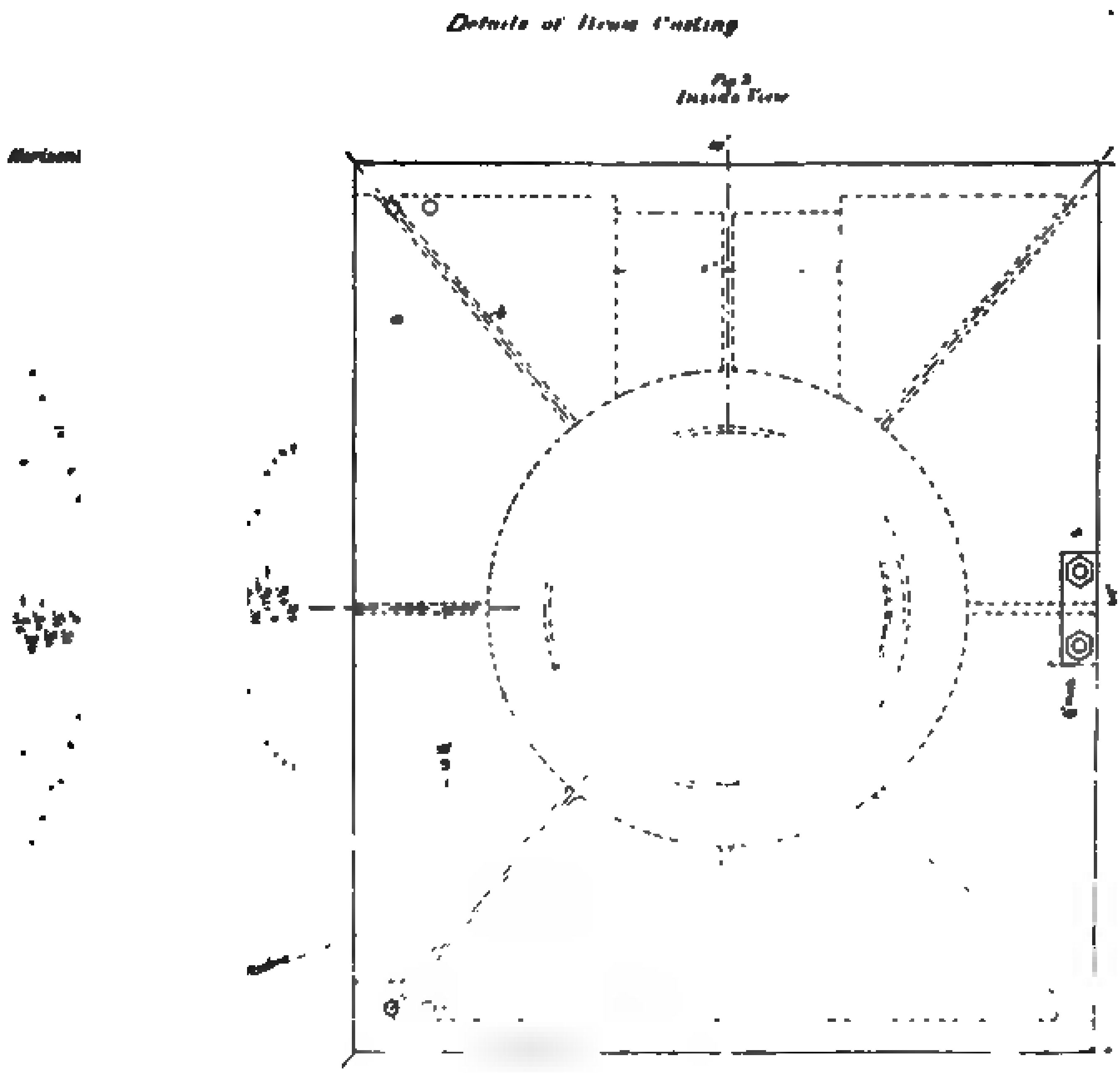
The details of the arrangement for measurements with simple free orifices are shown in Figures 2 to 14. In experiments of this description it is of course essential that the orifice shall be placed in a plane surface. It was therefore necessary to arrange the apparatus so that the curvature of the tank itself should not affect the flow. For this purpose a composition casting *a* (Figs. 2 and 3) is drawn up to the tank by eight $\frac{5}{8}$-inch bolts, as shown in Figure 3, which are screwed into the hub of the casting. The greater part of the casting is only $\frac{1}{4}$ inch in thickness, with eight strengthening ribs, as shown in Figure 2. In this casting is placed a piece, *c*, which is held in position by a ring-nut, *dd*, which can be screwed or unscrewed by a spanner. When it is desired to use large or long orifices the piece *c* will contain the orifice, and by having various pieces *c*, with orifices of different shapes and sizes, numerous experiments may be carried out. The composition casting *a* is thickened on one side to $\frac{3}{8}$ inch, as shown in Figures 2 and 3, to allow of the insertion of a sliding piece by means of which the horizontal dimension of a rectangular orifice may be varied, keeping the vertical dimension constant. When small orifices are to be used, it is not desirable to have them cut in as large a piece as the piece *c*. This piece *c*, therefore, as shown in Figure 3, is arranged to take a second piece, *o*, held in place by a second ring-nut, *d'*. Small orifices are made in pieces like the one *o*, as shown in Figure 3, and are of different sizes and shapes.

It is desirable that one orifice may be removed and another substituted in its place without completely emptying the tank. For this purpose a gate is designed to slide on the back of the casting *a*, so that, when it is desired to remove one orifice, the gate may be lowered and the water thus shut off, and a new orifice substituted in place of the old one. The gate may then be raised and the experiments continued. This gate and the fittings connected with it are shown in Figures 4 to 14. Figure 4 shows a view of the gate from the inside, Figures 5 and 6 horizontal cross-sections, and Figure 7 a vertical cross section. The gate is of cast iron, ribbed as shown, and is arranged to slide in guides bolted at the bottom to the casting *a*, and at the top to the tank. These guides are shown in Figures 8 to 11. In order that the gate may be raised without having to overcome the friction due to the pressure of the water over the entire surface of the gate, the rod *r*, by which the gate is raised, is attached to an

Steel Tank

Fig. 1.





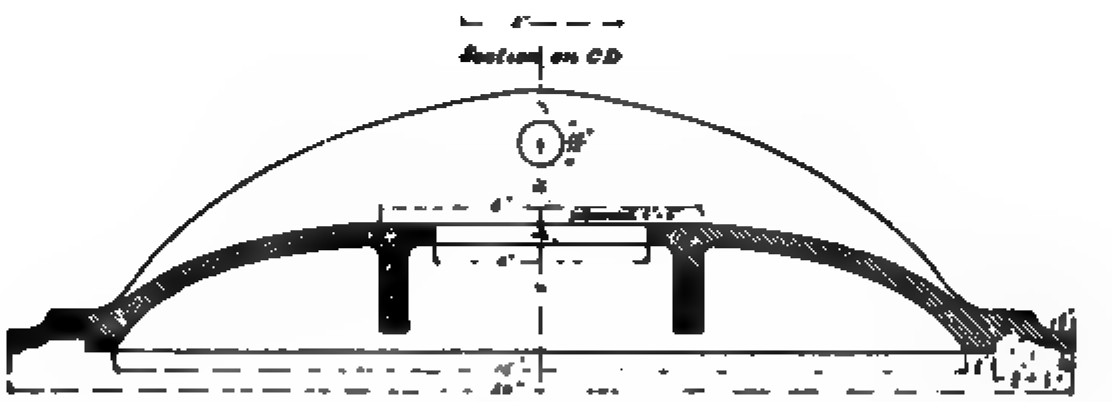


Fig. 5

Fig. 6

Fig 16

Side Elevation showing Soil Pipe

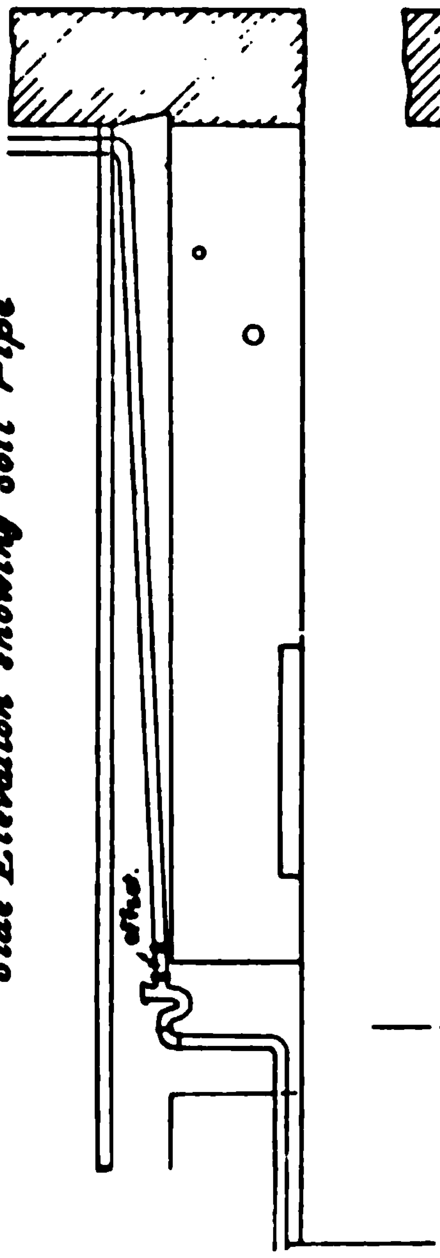
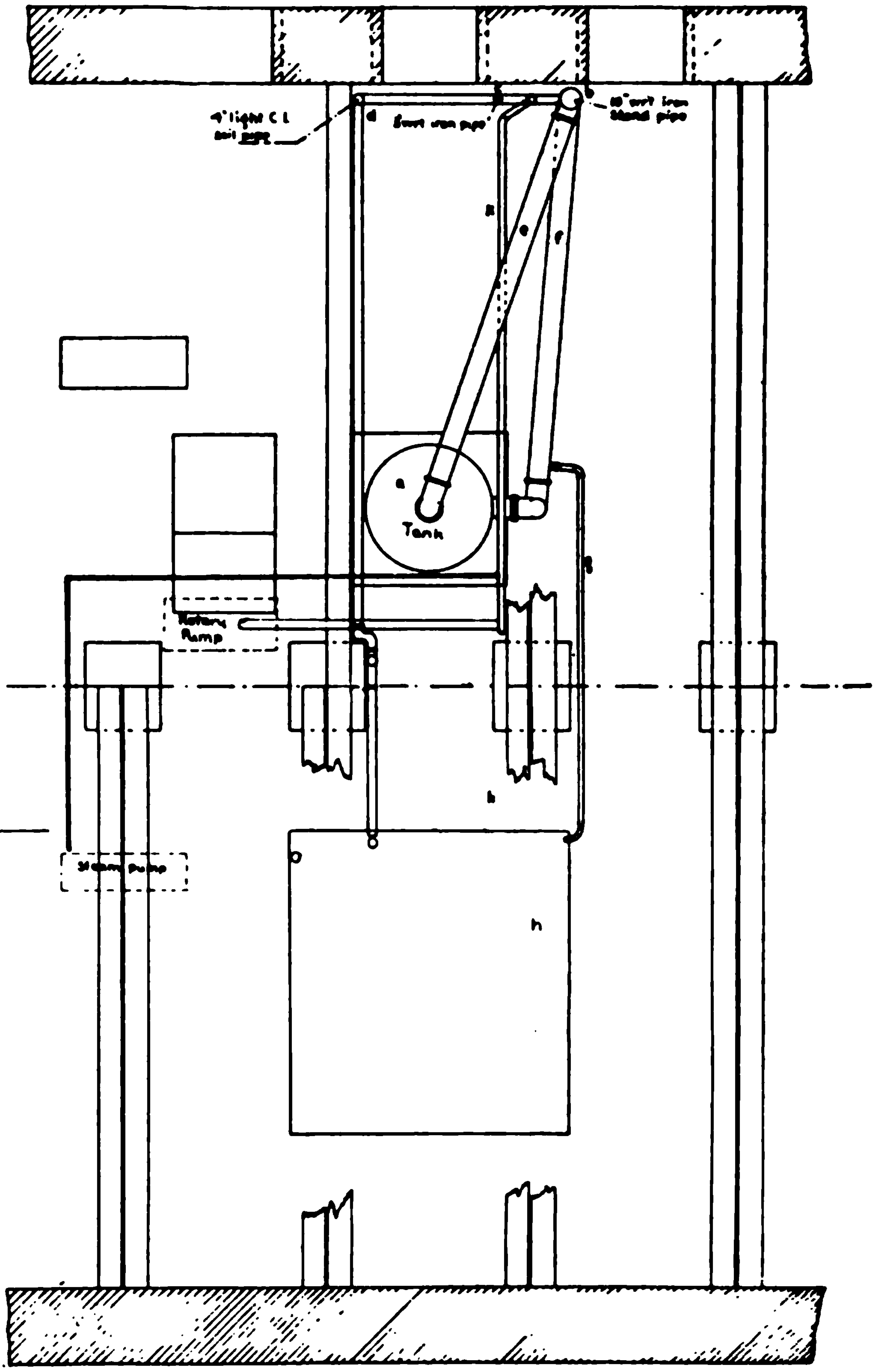


Fig 15

Plan of Sub-basement



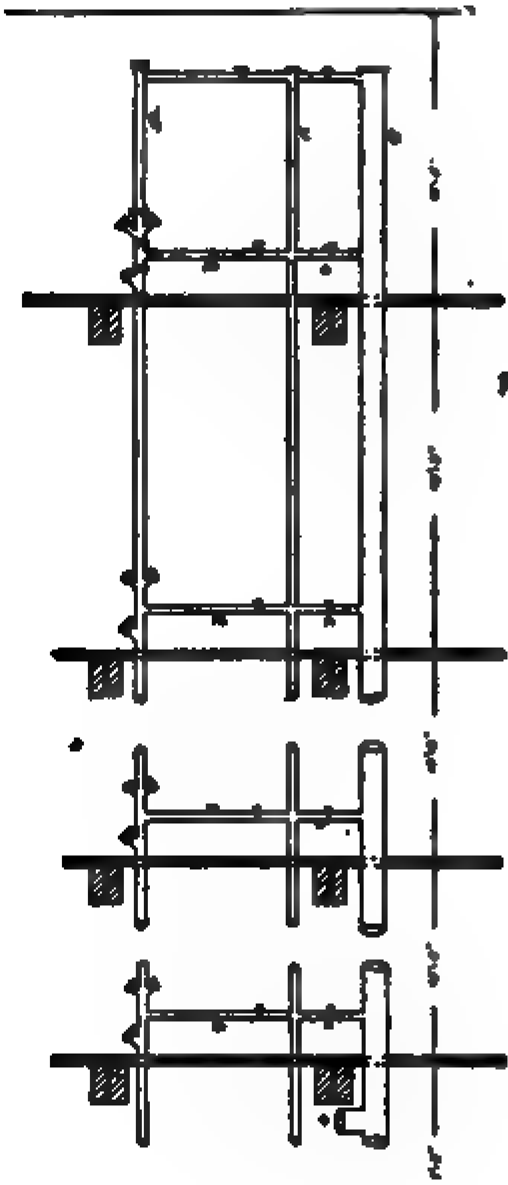


Fig 17

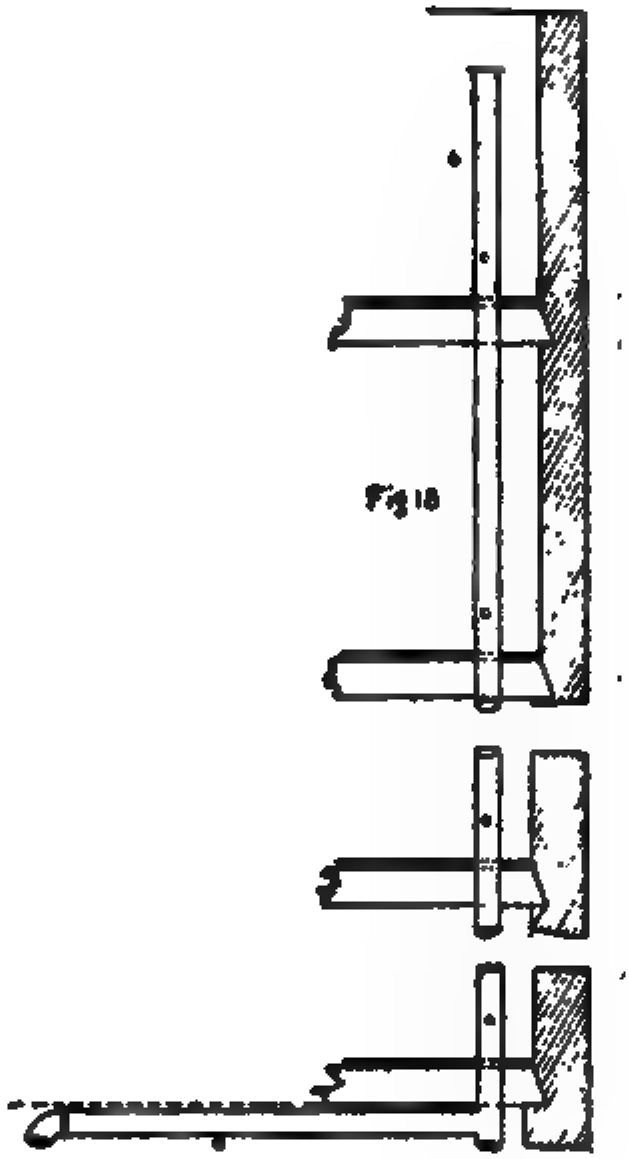


Fig 18

The eight vertical ducts are of necessity made to serve the dual purpose of supply and discharge. To adapt them to such purpose, a diaphragm is fixed in such way as to provide two channels having areas proportioned to the quantities of fresh and spent air to be moved through them to and from the successive stories, Fig 3. These diaphragms are made of sheet iron, which is secured by methods effectually preventing the leakage of air from the plenum into the exhaust conduits. Wherever practicable, the diaphragm is so placed as to remove the supply conduit from the outer walls, and to bring the discharge conduit against them.

Because of the small space occupied by the entire system, velocities of the air moved must be high. To secure to each register of the lower stories its proportion of air, and to prevent its going by such register under the momentum of its movement, deflectors are used, the area of each and the angle at which it is set controlling the air volume issuing from each register. Similar deflectors, set in a reverse position, are used for the outlets from the upper stories. To thoroughly break up and diffuse the swift flow of cool air in solid current from the register, diffusers, such as are shown in Fig. 1, are used with gratifying success.

The building accommodates some three hundred students, and the air supply is nearly 2,000,000 cu. ft. per hour, the fan running at 250 revolutions. The students are massed now here now there in class rooms, drawing rooms, and laboratories. Provision is made for a corresponding distribution or concentration of air supply, but the results without such alteration are so generally satisfactory that the valves are not used. Within the best filled rooms the largest proportions of carbonic acid thus far found are $\frac{7}{10000}$ to $\frac{7\frac{1}{2}}{10000}$, and the uniformity of the proportions in all parts of the rooms has been found exceptional.

The warming is effected by three systems. Because of the large amount of steam work done in the basement, air must be supplied in large quantities, and at a temperature ranging from 45° to 55°, according to laboratory work and outside conditions of weather. The eight distributing flues cannot supply air to the several floors or rooms at different temperatures. They must supply it at the temperature required by that room above the basement most easily warmed to the point desired. Therefore, it becomes necessary to provide means for supplying air through one system of conduits to the basement at, say

throttled drip-valve would allow steam to back into the coil and cause pounding. But the check-valve holds back the steam and allows the condensation to collect until its weight and the steam pressure combined force the valve open and the water out. The filling of the pipes with condensed water serves also the useful purpose of automatically regulating the length of their heated parts, and aids in maintaining the even temperature sought in the flues.

The heating is for the most part done by the exhaust steam of engines and pumps used in the building, and to avoid the possibility of returning oily water to the boiler the condensation is passed into the sewer. For the purpose of cooling this water; and of utilizing its heat, it is passed through 800 feet of continuous 1¼" pipe, made into a trombone coil 38 pipes high, 7' long, and 3 pipes deep, placed before the inlet window, Fig. 2. In mild weather the condensation is so small that it goes to the sewer cold. When the outside temperature is low that of the chilled water is higher, the rate of condensation slightly exceeding that of the chilling. The maximum rate of flow in severe weather is about 1 cu. ft. per minute.

The fan and combined heater, with directly attached engine, is of the Sturtevant pattern and make, with a large by-pass over the heater. The fan is 6' in diameter, and at 250 revolutions per minute supplies 38,000 cu. ft. of air. Outside the inlet window a roaring sound of rushing air may be heard, due to the high volocities inflicted on the air in transit through the coil and fan because of want of space to give it larger passage and lower velocity. Within this sound is not heard, partly on account of the noise of moving machinery.

The low pressure under which the heating system is worked and the irregular flow of condensed water, due in part to the intermittent supply of steam to the pipes, make the use of any ordinary steam trap impracticable. The method adopted for the relief of the New Building system having given entire satisfaction, it has been adopted in this system also. It consists of a syphon trap made of a 4" pipe 18' long driven vertically into the ground, bushed at the top and tapped at the side. Through the bushing runs a 2½" pipe to within 1' of the bottom of the large pipe. This pipe is bushed at the top, tapped at the side, and open at the bottom. The tap receives the water from the returns. The bushing receives a 1" pipe, which drains the supply main at a higher pressure than the return, and runs inside the 2½" to within 1'

	New Building.	Eng. Building.
Area of inlet windows, ...	106 sq. ft.	33 sq. ft.
Area through steam coil, ...	120 "	20 "
Area of fan mouth, ...	65 "	13.3 "
Area of fan discharge, ...	150 "	12.2 "
Area of floor occupied by fan room and heating chamber, ...	720 "	120 "
Area of main heating coil, ...	2200 "	1200 "
Area of flues for supply and discharge of air,	240 "	96 "
Number " " " " " " "	83 "	8 "
Air volume supplied, cu. ft. per hour, .	3,600,000*	1,950,000
Fan revolutions, ...	80 to 100	250

* In mild weather this is increased to 6,600,000,— fan revolution 100, and indicated horse-power expended 17. The fan is now run by an independent engine, and not as heretofore at a fixed speed.